REPORT ON WATER-GAS.

By a Special Committee Appointed by the Judges of the "Novelties" Exhibition, Franklin Institute.

15

Philadelphia:
1886.

REPORT ON WATER-GAS.

[MADE BY A SPECIAL COMMITTEE APPOINTED BY THE BOARD OF JUDGES OF THE "NOVELTIES" EXHIBITION.]

THE COMMITTEE—to which was assigned the duty of formulating the reasons on which the Board of Judges has based its recommendation of an award of a GRAND MEDAL OF HONOR to THADDEUS S. C. LOWE, of Norristown, Penna.—respectfully submits the following report:

The published announcement of the Board of Managers of the FRANKLIN INSTITUTE, respecting this award, reads as follows:

"A GRAND MEDAL OF HONOR to the invention or discovery shown at the Exhibition which shall be held to contribute most largely to the welfare of mankind."

By the terms of this announcement, therefore, the selection of the subject is limited to an invention or discovery shown at the Exhibition; and it is required that the subject chosen shall possess the qualification of pre-eminent usefulness, in the sense that its advantages and benefits may be enjoyed by the greatest number.

It is the opinion of your committee that an invention or discovery that notably cheapens the cost of fuel and light, and that is not circumscribed in its applicability, but that may be widely utilized, should merit your most respectful consideration.

Both directly and indirectly, cheaper fuel and cheaper light contribute largely to the welfare of mankind; directly by increasing personal comfort and safety, and indirectly by cheapening the cost of innumerable manufactured products; and, in the judgment of your committee, to crown a meritorious invention or discovery of this character, with special distinction, would be worthy of the the utilitarian spirit of the FRANKLIN INSTITUTE.

In order that you may form an intelligent opinion of the merits of the Lowe Process for the Manufacture of Water-Gas, your committee has investigated the state of the art prior to, and up to the time of its introduction. A brief *résumé* of the results of this inquiry is given herewith, with suitable references appended.

Fontana.

So far as your committee can ascertain, FONTANA was the first to observe, and to call attention to, the reaction which takes place between steam and incandescent carbon, and which results primarily in the formation of one volume of hydrogen gas and one of carbon monoxide from one volume of steam.

John Ibbetson, 1824.

JOHN IBBETSON appears to have been the first who attempted to apply FONTANA'S observation in the practice of gas manufacture (an abstract of Ibbetson's British Patent No. 4,954, March 15, 1824, is given below, and a sketch of his apparatus is appended and marked *Appendix A*.

Following Ibbetson's come a legion of patented processes, in which inventors with more or less ingenuity, have endeavored to take advantage of the interaction of steam and carbon at elevated temperatures, either as an accessory to, or, as the foundation of, the manufacture of gas for illumination or heating.

YOUR COMMITTEE has embodied in this report only such references as, in its judgment, have a direct bearing on the development of water-gas processes from a technical standpoint.

In tracing the development of the art of producing water-gas from its crude beginnings to its present highly perfected state, all the processes, in which the reaction of steam and incandescent carbon or carbonaceous substances is introduced, may be divided into two groups:

(*1.*) *Those in which steam is introduced into retorts containing*

carbon, the temperature of which is maintained by combustion external to the retorts; and

(2.) *Those in which steam is admitted into retorts or furnaces containing carbon, which has been previously heated by partial combustion of its own mass, or by internal combustion.*

In the processes embodied under both of these heads, the steam may or may not be superheated before it is introduced to the retorts or furnaces, and the waste heat of the furnace gases, and that carried by the finished gas may or may not be utilized.

It thus appears that the development of water-gas manufacture proceeded along two quite distinct lines; one, having for its chief distinguishing feature the system of *external* firing, and the other that of *internal* firing. The capabilities of both systems have been very fully brought out, and both are in use at the present time. A consideration of both systems will therefore be necessary to an understanding of their merits.

CLASS I.—PROCESSES EMPLOYING EXTERNAL FIRING.

These may be conveniently subdivided into two groups:

(*a.*) *Those in which saturated (or non-superheated) steam of comparatively low temperature and pressure is employed; and*

(*b.*) *Those in which superheated steam is employed.*

(*a.*) PROCESSES IN WHICH NON-SUPERHEATED STEAM IS USED.

This group is represented by the following processes:

John Ibbetson, 1824.

JOHN IBBETSON'S process, patented in England, May 15, 1824 (British Patent No. 4,954), is the earliest of which your committee finds any record.

This invention embraced an apparatus "for the decomposition of water under the process of passing steam through ignited coke, or other carbonaceous matter as an auxiliary in the production or manufacture of inflammable gas from coals, peat oil, tar, or other combustible substance." His second claim is "causing the volatile results which proceed from the decomposition of water, or from the decomposition of coals, peat, tar, oil, or other combustible matters in their nascent state, or in the state in which they rise, and before they undergo any process of cooling, to pass through ignited coke or other carbonaceous matter."

In this ingenious but impractical apparatus (of which a sketch is appended, marked *Appendix A*), the fire-brick retort is built around a central fire-box, and, at the same time the flame and products of combustion are caused to descend and play around the exterior of the retort. Steam is injected through perforated clay pipes, and the gas is led to the "hydraulic main or other receiver."

Selligue, 1835.

ALEXANDRE SELLIGUE, an eminent French technologist, in 1835 (*Brevet d'Invention, Nro. 9,800, 4ième Brevet d'Addition*), employed

semi-cylindrical retorts, arranged in pairs, vertically, and heated by external firing from above and below, by an arrangement of grates at two levels. The interior of each retort is divided into two compartments by a vertical fire-brick partition, and the gas formed is withdrawn at the opposite side. A sketch of this apparatus is appended and marked *Appendix B*.

White, 1847.

In 1847, Stephen White (B. P., 11,654), patented an apparatus consisting of three vertical retorts, the first two of which contain, near the bottom, a collander filled with iron plates or wire and lime. They are then filled up with charcoal, coke or anthracite, and are heated to whiteness either by the "usual furnace" or "the apparatus known as Daniell's galvanic battery, the positive and negative wires being conducted into the retorts" (!)

A small stream of water is allowed to flow into the first retort, and the vapor passes downward, and by a conducting pipe at the bottom into the second retort, from which the gases pass into the third retort.

The latter contains coils of iron chains, which are maintained at a moderate red heat, and is supplied with a suitable stream of oil, fat, tallow or tar, which drips on the heated iron. The resulting gas passes from the retort to the condenser, and thence to the gas-holder.

This patent is almost identical with B. P. 8,126, granted to John Alexander Phillip de val Marino, June 22, 1839.

Lancaster & Smith, 1855.

Lancaster & Smith, in 1855 (B. P. No. 1,181), proposed to pour water or inject steam into the retorts during the distillation of gas from coal.

Prince, 1861.

In 1861, Alexander Prince (B. P. 1,397) proposed to introduce a mixture of tar and water into a retort containing incandescent

charcoal. "The steam thus decomposed with the red hot coal forms hydrogen and carbonic oxide gas, which, being likewise in a glowing condition, decomposes the present carburet and combines with it."

(*b*) PROCESSES IN WHICH SUPERHEATED STEAM IS USED.

This group is represented by the following processes:

Cruckshanks, 1839

In 1839, ALEXANDER CRUCKSHANKS obtained a patent (B. P. No. 8,141) for a vertical retort filled with carbonaceous material, and heated by external firing. The injected steam is superheated by being led through pipes that pass through the flue and fire-box, and the heat of the waste gases from the furnace as well as that from the gas produced in the retort, is utilized to heat the water supplied to the boiler, and to generate the steam required by the retort. The claims in this improved method for obtaining an inflammable gas from the decomposition of water, are:

(1.) "That the heated gas from the retort and the hot air from the furnaces are applied to generate and to heat the steam, as also to heat the water with which the boiler is supplied."

(2.) "That the steam is introduced to the retort at the temperature at which it is decomposable by carbonaceous substances, whereby retorts of much larger dimensions may be used than with steam at lower temperature."

A sketch of this apparatus is appended and marked *Appendix C.*

Lowe, 1846

In 1846, GEORGE LOWE (B. P. No. 11,405) suggested blowing superheated steam into retorts, in which gas is being made, the steam being admitted at a point as far as possible from the point of exit of the gas.

Barlow & Gore, 1851.

In 1851, BARLOW & GORE (B. P. No. 13,593) passed steam,

heated to a high degree, if desired, over incandescent coke, and then over coal which was being converted into gas.

Dinsdale, 1854.

In 1854, THOS. DINSDALE (B. P. 1,389) patented an apparatus by which superheated steam was injected into retorts during the distillation of coal for gas making.

Jacquelin, 1854.

AUGUSTIN JACQUELIN proposed, in 1854 (B. P. 1,840), to expose carbon alone, or in combination, to the action of an excess of steam at a high temperature, so as to convert the carbon into carbon dioxide and obtain pure hydrogen.

This is not the object of modern water-gas processes, and the method of JACQUELIN required externally heated retorts.

Sanders, 1858.

A great advance upon the foregoing processes is that of J. MILTON SANDERS, patented in the United States July 27, 1858. (U. S. Patent No. 21,027.)

This process attracted much attention at the time, and was experimentally used in several localities. The trials of the process at the Girard House, in this city, in 1859–1860, may be recalled by some of the members here present.

The Sanders Water-Gas process employed L-shaped retorts of cast iron, placed vertically, which were charged with charcoal of oak or maple, and heated to incandescence by a coke fire applied externally. An atomizer delivered a spray of superheated steam and melted rosin into the top of the retort, and the gas was passed out from the horizontal leg of the retort. It was submitted to substantially the same treatment as ordinary coal gas.

The process did not prove commercially successful, principally it appears, because of the excessive destruction of the retorts. Your committee has been able, through the politeness of Mr. S. LLOYD WIEGAND, to obtain a sketch of the Girard House plant,

with a letter giving some details of interest. This letter and a sketch of the Sanders apparatus are appended and marked *Appendix D*.

Isoard, 1860.

In 1860, ISOARD (B. P. 2,782, 1857,) endeavored to introduce a process for producing illuminating gas, rich in hydro-carbons, by the action of superheated steam on coal, oils, etc. The apparatus required the use of retorts, externally heated and the gas obtained was essentially different from water-gas.

Gillard, 1860.

GILLARD'S process (B. P. 1,087, 1860,) consisted in injecting superheated steam into a fire-brick lined retort containing wood, charcoal, or any carbon free from sulphur, and the resulting gas was purified by lime.

Harris–Allen, 1871–72.

Passing by numerous patented procedures of minor importance, the class of processes embraced in this division of the subject appears to have reached its highest state of development in the patents (No. 112,593, March 14, 1871, issued to G. M. HARRIS, of Elizabeth, N. J., and No. 129,951, July, 30, 1872,) issued to G. M. HARRIS and HORATIO P. ALLEN, of New York.

The first of these is for fire-clay horizontal double retorts for the production of water-gas by the delivery of "superheated steam in finely divided jets through incandescent carbon."

The second (Harris and Allen, No. 129,951, July 30, 1872,) is for certain "improvements in the form, arrangements and setting of retorts for the production of permanent gases from steam by the action of incandescent carbon;" describes a gas "generator" of vertical fire-clay retorts for the production of water-gas by the delivery of superheated steam in finely divided jets through incandescent carbon. This arrangement of apparatus seems to be a very effective form, and may stand as the typical representative of the class of water-gas systems here considered. The Harris and

Allen plant, with certain improvements in minor details, is in use at the works of the Citizens' Gas Company, in Poughkeepsie and at Rondout, N. Y. (Drawings of these patents are appended and marked *Appendix E.*)

CLASS II.—PROCESSES EMPLOYING INTERNAL FIRING.

THE WATER-GAS PROCESSES at present in general use, belong to this class. The earliest of these were intended to be merely accessories to the usual coal-gas process. Some employed saturated steam, others superheated steam. In some, provision was made for the utilization of waste heats; in others, this was neglected.

A *résumé* of the several processes, which have contributed materially to the development of this class of water-gas processes, is given in what follows:

Lowe, 1831.

In 1831, GEORGE LOWE (B. P., 6,179,) invented an apparatus to be applied to retorts, coke ovens or furnaces of gas works, for the purpose of receiving the hot coke drawn therefrom, and generating gas by means thereof. The principal object of this apparatus appears to have been the utilization of the heat of the incandescent coke. The apparatus consisted of a fire-brick lined cylinder of cast or wrought iron, arranged under a hopper below the floor of the retort house, and in front of a bench of retorts. The cylinder is of convenient size to receive the coke drawn from a bench of retorts as soon as they are discharged, and is furnished with a grate at the bottom, on which the coke may rest. Within a short time after the cylinder is thus filled, the draught produced by the hot coke accelerates the combustion so much that the coke is heated to whiteness. the top and bottom of the cylinder are then closed by suitable lids or covers, and steam or "other matter" is introduced through a pipe leading into the upper portion of the cylinder. The gas produced passes out by a pipe at the lower end of the cylinder, and, it is recommended that this pipe have three valve branches, connecting with the middle and upper portions of the cylinder, in order that the gas may be drawn only from the hottest portion. It is added "that if the gas made in this manner be produced from

steam, it is evident that it will not pass off from the cylinder in a state fit for illumination, but must be subsequently submitted to the known process of saturation with the vapor of essential oils, or other similar illuminating matter, in order to render it fit for use."

The process of Mr. Lowe is apparently the *first* recorded description of the production of a pure water-gas, and he is the first to describe the process of making this gas an illuminant by carburation subsequently to its production.

From the description above given, however, it is evident that Mr. Lowe's process was designed to be merely an accessory to the usual coal gas process, his principal object being, as is manifest from the context, to utilize the heat of the incandescent coke as it is withdrawn from the retorts. A sketch of George Lowe's apparatus is appended, marked *Appendix F.*

Kirkham Brothers, 1852.

In 1852, John and Thos. N. Kirkham (B. P. 14,238) patented a process by which a mixture of steam and air was passed over coal heated to nearly the melting point of iron; the waste heat of the furnace and of the gas generated being used to produce steam, and to heat the air required to maintain the combustion. The resulting gas is a mixture of hydrogen, carbon monoxide, carbon dioxide, and a large proportion of nitrogen. The carbon dioxide was removed by lime, and the gas passed over volatile hydro-carbons when it was required for illumination.

In 1854, the Kirkham Brothers improved their process (B. P. 1,882) the special improvement being a heated chamber for carburetting the gas. A sketch of the Kirkham apparatus is appended and marked *Appendix G.*

The product of this process differs from water-gas in containing a large proportion of nitrogen, but the process nevertheless embraces the important feature of utilizing the heat of the furnace products to generate the steam required in the operation of the process, and to heat the air blast to a high temperature prior to its entrance to the furnace.

It is apparent that by modifying this process so as to introduce the air and steam alternately, and not simultaneously, a true water-gas would be produced, under conditions not incompatible with commercial success. This water-gas could be made available either as such, for fuel, or by carburation or other means, as an illuminant.

Your committee is advised that with the modification just named (which it must be confessed is a material one), the Kirkham process is practised in New York, and known under the name of the Municipal Process.

Fages, 1860.

In 1860, Fages (*Génie Industrial, 1860*, 329, *Wagner's Jahresbericht, 1860*, 582) devised a *gazogène* for producing hydrogen for illuminating purposes. The furnace resembled a cupola furnace. Coal was introduced through a removable cover, and the heat was produced by internal firing, the refuse being withdrawn through a suitable door. The charge was blown up by means of a fan, the cover being removed and the products of combustion being allowed to escape. When the proper temperature was attained, the blast was stopped and steam was admitted. The admission of the steam and the blowing of the coal were so alternated that the temperature was maintained approximately uniform, and the operation made practically continuous. The heat of the waste gases, and of the gas generated was apparently not utilized. Carbon monoxide was to be removed from the gas by leading the latter through a highly heated chamber formed in the interior of the furnace where it came in contact with a jet of superheated steam. By the interaction of steam and carbon monoxide under these conditions, it was anticipated that carbon dioxide and hydrogen would be formed. The former was to be removed by subjecting the gas to the usual purifying process, leaving hydrogen as the final product. A sketch of the Fages *gazogène* is appended, marked *Appendix H.*

Fages seems to have been the first to employ the procedure of introducing air and steam *alternately* into an internally-fired gas generator, which forms an essential feature in modern processes of this class. The absence of all provision for the utilization of the waste heat evolved in blowing up the charge, and the impossibility of preventing the rapid destruction of the secondary decomposing chamber in the interior of the *gazogène* were weak features, which doubtless contributed to the failure of his system.

Siemens, 1856.

In 1856, Frederick Siemens devised and patented an improved arrangement of furnaces, which has since become indispensable in the metallurgical arts, and of which the essential features are described in the following extract from his British patent (No. 2,861, 1856).

Abstract.—My invention consists of certain arrangements of furnaces, which have for their object to recover the heat which is still contained in the flame or products of combustion on passing away from the fire-place, or heated chambers, or flues, towards the chimney, by causing that heat or a greater portion thereof, to be imparted to the current or currents of atmospheric air, gas, or other materials employed to maintain combustion in the same or other fire-places, by which arrangement heat may be accumulated to an unlimited extent (consistent with the materials employed) and great economy of fuel is effected.

The principal claims are as follows:

"*Firstly.* Constructing furnaces in such manner that the heat of the products of combustion is abstracted by passing the same through chambers containing refractory materials so arranged as to present extensive heat-absorbing surfaces, and is communicated to currents of air or other gases by passing the latter currents alternately over the same heated surfaces.

"*Secondly.* Constructing furnaces in such manner that the products of combustion and currents of fresh air or other gases destined to support combustion, are directed at intervals in opposite or

nearly opposite directions, through chambers containing refractory materials, so arranged as to present extensive surfaces, with a view of effecting an exchange of temperatures between the two alternate currents.

"*Thirdly.* Arranging two chambers containing materials presenting extensive surfaces in connection with one furnace containing one or more fire-places, in such manner that, while the materials contained in one chamber are being heated by the currents containing the products of combustion, the heated materials in the second chamber impart heat to the current or currents of air of other gases intended to maintain combustion, and vice-versa, the heating and heated currents being passed alternately through each of the chambers in opposite directions.

"*Fourthly.* Arranging a valve or valves in connection with furnaces in such a manner, that, by changing the position of the same from time to time, the current or currents of air and heated gases in the furnace and chamber or chambers containing heated materials are reversed in their direction, but are made to enter and issue without interruption through the same apertures, so that they may be impelled by one chimney or blowing apparatus.

"*Fifthly.* Arranging two or more pairs or sets of chambers containing refractory materials, and which I have termed 'regenerators' in relation to one furnace, or one or more fire-places, in such manner, that, while one pair of regenerators serves to transfer the heat of one heated current to a current of fresh air supporting combustion, a second pair of regenerators may be employed to impart heat to the carburetted hydrogen, carbonic oxide, or other gaseous material intended to enter into combination with the heated air produced by the first mentioned pair of regenerators."

Siemens Brothers, 1863

Seven years later, C. W. and Fred'k Siemens made considerable improvements in the details of this regenerative furnace. An abstract of these improvements, as described in their British patent

(No. 972, 1863), is appended to this report, with drawings, and marked *Appendix I.*

The Siemens system of combustion comprises two important features: (1.) The production of a gaseous fuel from solid carbonal ceous materials; and (2) the utilization of the heat of the initia- combustion products by passing the same, alternately with air, through chambers constructed of refractory materials (checkered brick-work), arranged in any convenient manner contiguous to the primary combustion chamber, and in which chambers the heat of the products of the imperfect combustion of solid fuel is intermittently stored up and imparted to the entering air.

These improvements gave, for the first time, to the metallurgical arts, and with notable economy, a highly perfected system of supplying gaseous fuel, and the command of much higher temperatures than had hitherto been attainable.

It does not, however, appear in any of the descriptions given by the brothers SIEMENS of their improvements in furnaces, that they at any time contemplated their application to the production of water-gas by the introduction into the primary combustion chamber of the air and steam alternately; nevertheless the regenerative system of combustion here described plays an important part in the development of water-gas manufacture, inasmuch as it constitutes one of the distinguishing features of the only conspicuously successful water-gas process of to-day.

Lowe, 1875.

We come at length to the objective point of the foregoing historial sketch, namely: "*The Lowe process and apparatus for the production of water-gas for heating and iluminating purposes*," which constitutes the subject of letters-patent granted to THADDEUS S. C. LOWE, of Norristown, Pa., September 21, 1875. (See U. S. Letters-Patent 167,847, of which a copy, with drawings, is hereto appended and marked *Appendix J.*

The process described therein contains the following elements, viz.:

(1.) A combustion chamber or generator, designed to be charged with carbonaceous substances, and heated by internal combustion;

(2.) The admission of steam and air alternately into a gas generator heated by internal combustion; and

(3.) The employment of effective methods for preventing the waste of heat at every stage of the process, by

(*a*) The employment of superheaters (corresponding to the regenerators of SIEMENS) in which the partially oxidized combustion products given off from the generator are completely burned, and the heat of the same is abstracted by their passage through extended surfaces of refractory materials (checkered brick-work), in which the heat is stored up, and subsequently utilized for superheating the steam employed in the process, or in fixing the illuminating gas produced;

(*b*.) By causing the last portions of the heat of the combustion products of the superheater to heat the air-blast prior to its admission to the generator, or to generate the steam required in the operation of the process; and

(*c*.) By causing the water-gas, which leaves the generator at a high temperature, to pass through the flues of a boiler, or similar contrivance, by which the heat contained therein is caused to generate steam or heat the air-blast.

IT IS THE BELIEF of your committee that the combination of elements here described, constitutes a process of water-gas manufacture more effective and more economical than any that had hitherto been devised. Each of these elements, either separately or united in part, had previously been suggested and applied—the principle of internal combustion, for example, by GEORGE LOWE, in 1831; the mode of admitting air and steam to the generator alternately, by FAGES, in 1860; the heat economizing features, by CRUCKSHANKS, in 1839; by the KIRKHAM BROTHERS, in 1852, and in an eminent

degree by the brothers SIEMENS (1856–63), but the combination of the three in practicable form for the special purpose of producing a gaseous product suitable either for fuel or illumination, does not appear to have been made or suggested prior to the date of the first publication of what has since come to be known as the Lowe process.

That this combination of elements constitutes a material improvement in the practice of the art of water-gas manufacture, the committee is unanimously agreed. That it has demonstrated its great utility, is proved beyond question by the facts of history accessible to all.

A glance at these will show that the Lowe process, or this process, *with unessential modifications in details*, since the year 1874, when the first plant was put in operation at Phœnixville, Pa., (where it has remained in continuous use to the present), has been introduced into more than 100 cities and towns in the United States and Canada (a list of localities where water-gas is in use is hereto appended and marked *Appendix K*).

Measured, therefore, by the standard of success, it has certainly earned the right to claim a respectful consideration by the members of an institution which has ever been conspicuous for its devotion to the utilitarian side of science; and, it would be a grave injustice to seek to evade the inference, to which the inventor, in the absence of direct evidence to the contrary, is rightfully entitled, that the success of the invention is the best evidence of its value.

Leaving the facts presented in the foregoing summary of the history of water-gas, and of MR. T. S. C. LOWE's connection therewith, to speak for themselves, it may be proper for the committee to direct attention to the numerous appliances and devices for utilizing water-gas for heating and illumination, which formed so interesting a portion of the exhibit of the Lowe Manufacturing Company, at the late exhibition, and which showed much ingenuity, and an appreciation of the importance of attention to minor details, which is praiseworthy.

These matters are fully treated of in the report of the Judges of Group 12 A, and the committee refers to this for much information that may properly supplement this report. (An extract from the report of Judges of Group 12 A, embracing the portion relating to the Lowe Manufacturing Company's exhibits, is hereto appended and marked *Appendix L.*

In conclusion, the committee has acted in the belief that it would best perform the duty assigned to it, by placing at the service of the judges a concise summary of the development of the art and practice of water-gas making, exhibiting as clearly as possible the part which the inventions of MR. LOWE have played therein, leaving the judges free to take such action as they may see fit.

Respectfully submitted, by

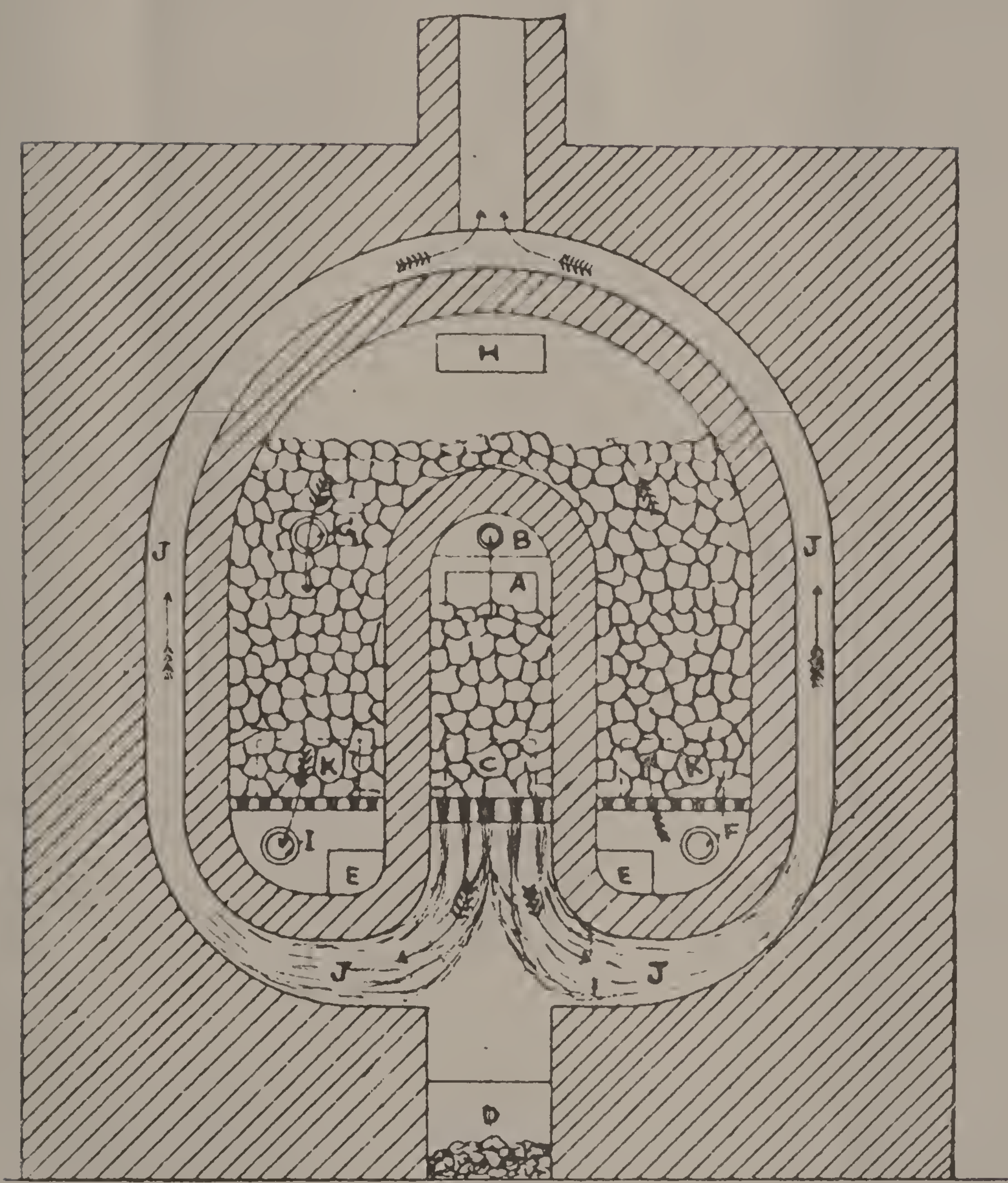
WM. H. WAHL, *Chairman.*
WM. H. GREENE,
WM. D. MARKS.
SAMUEL P. SADTLER,
LEMUEL STEPHENS,
Committee.

Philadelphia, May 1, 1886.

APPENDICES.

Appendix A.

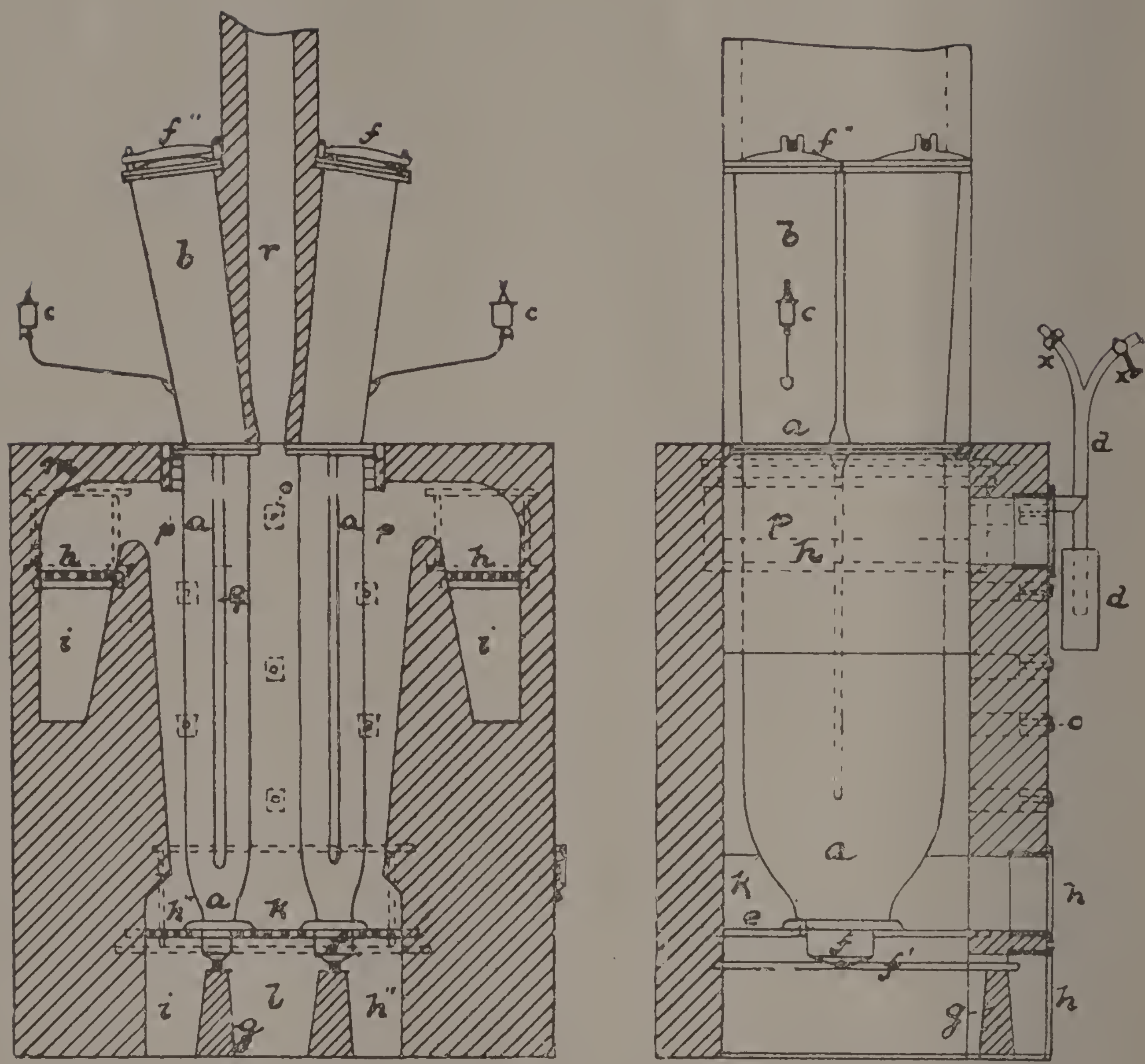
John Ibbetson.—1824.

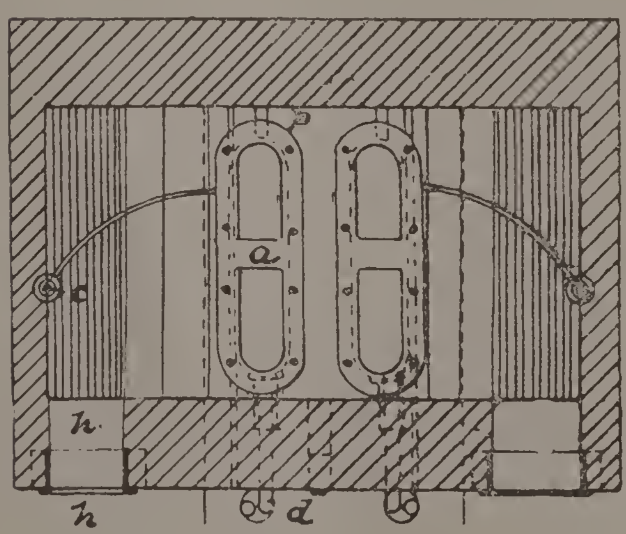


A—Charging Door of Furnace.	*H*—Charging Door of Retorts.
B—Blast-Pipe.	*E, E*—Ash Doors.
C—Lighting Door.	*F, G*—Steam Pipes.
D—Ash-pit Door.	*I*—Gas Escape Pipe.
J, J—Flues.	*K*—Cleaning Door.

Appendix B.

Alexandre Selligue.—1835.

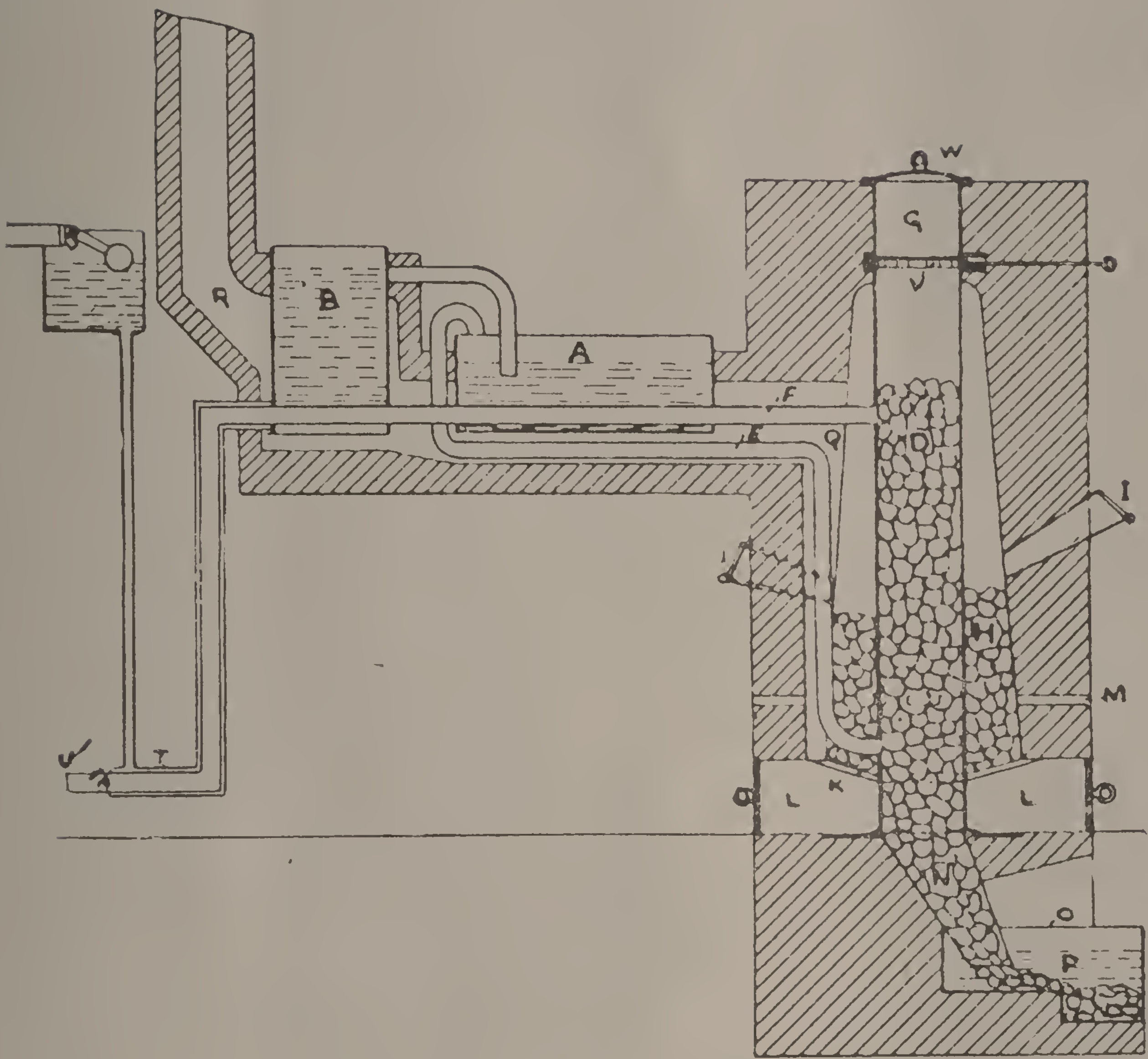




a—Retorts.
b—Water Receivers.
c—Water Supply Pipes.
d—Gas Escape Pipes.
e—Fire-Grate.
f, *f′*, *f*—Removable Covers.
h—Upper Fire-Grate.
i, *l*—Ash-Pits.
m—Brick-work of Furnace.
o—Sight-Holes.
q—Division for Draft.
r—Smoke Stack.

Appendix C.

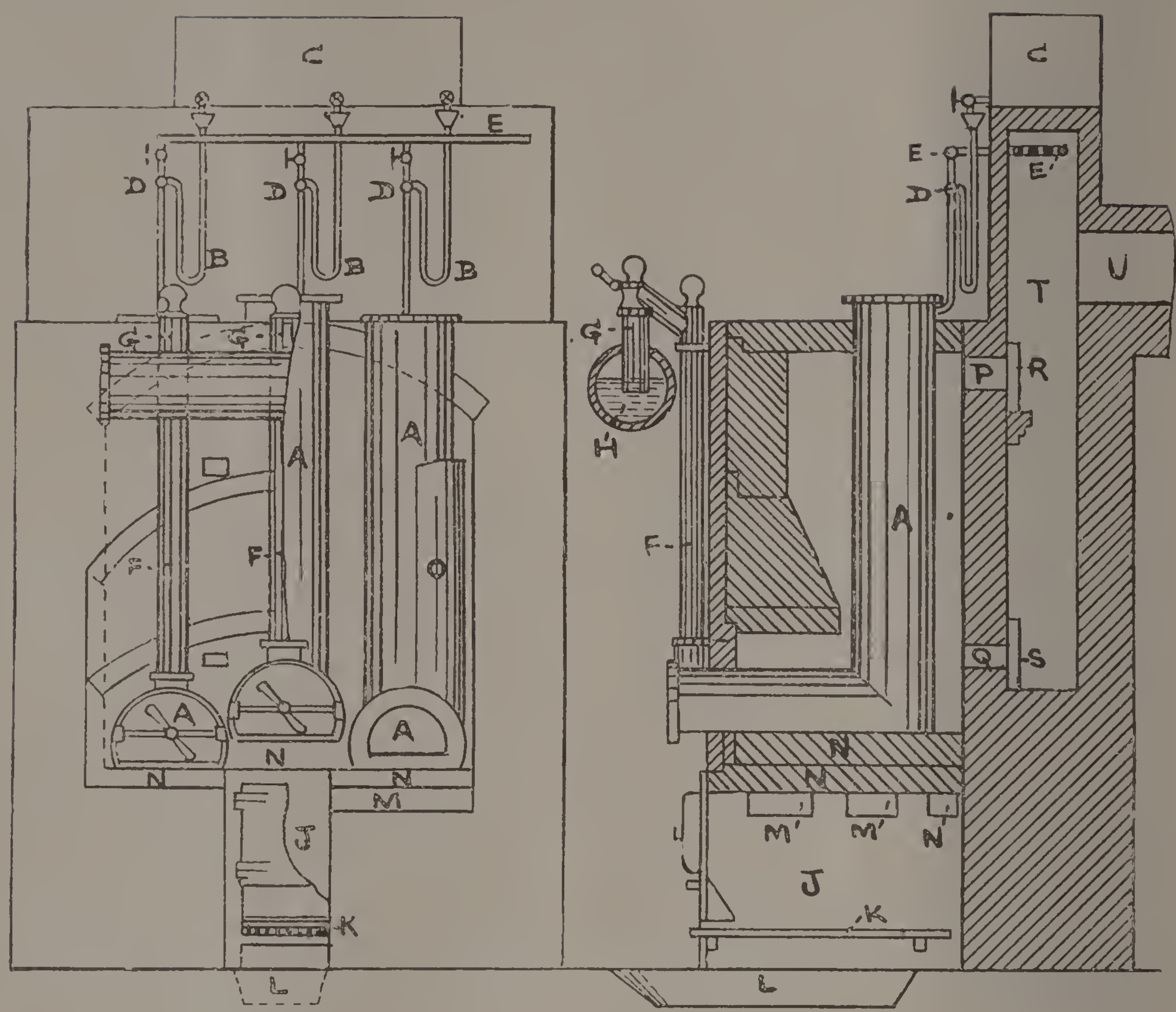
Alexander Cruckshanks.—1839.



A—Steam Boiler.
B—Hot Water Tank.
C—Cold Water Supply.
D—Retort.
E—Steam Pipe to Retort.
F—Gas Escape Pipe.
G—Retort-Charging Chamber.
H—Fire-Place.
I—Charging Hoppers.
K—Fire-plate.
L—Ash-pit.
M—Blast Pipes.
N—Refuse Chamber.
O—Refuse Cistern.
P—Refuse Box.
Q—Main Flue.
R—Chimney.
T—Water Heater.
U—Gas Main.
V—Charging Valve.
W—Charging Cover.

Appendix D.

J. Milton Sanders.—1858.



A—L-Shaped Retorts charged with Oak Charcoal and heated to incandescence.

(*Material—Cast Iron.*)

B—Inverted Syphons delivering melted rosin from Tank to Retort *A*.

D—Atomizers delivering superheated Steam from Pipe *E* into Retort *A*, with melted rosin.

F—Pipe terminating in Drip-Pipes *G*, delivering Gas into Hydraulic Main *H*.

J—Furnace.

K—Grates.

L—Ash-Pit with Water-Trough.

M—Flues.

N—Bed-Tiles supporting Retorts *A*.

O—Fire-Clay Sheath to protect Retorts from fusion.

P and *Q*—Flues provided with Dampers *R* and *S*, leading to Chimney through Flues *T* and *U*, containing Steam Pipe *E* for superheating purposes, and supporting and heating Rosin Tank *C*.

Appendix D.

PHILADELPHIA, February 1, 1886.

DR. WM. H. WAHL, *Dear Sir* :—I send herewith a drawing of the water-gas plant that was in use at the Girard House in this city in 1859 and 1860, and also at Aurora, Ind., Laconia, N. H., about the same date.

The process was known as "Sanders Water-Gas."

Besides the generating apparatus, a dry lime purifier, a washer and condensing pipes were used. These were of the same construction as those then used for coal-gas works at the Philadelphia and at the Manhattan Gas Works, New York City.

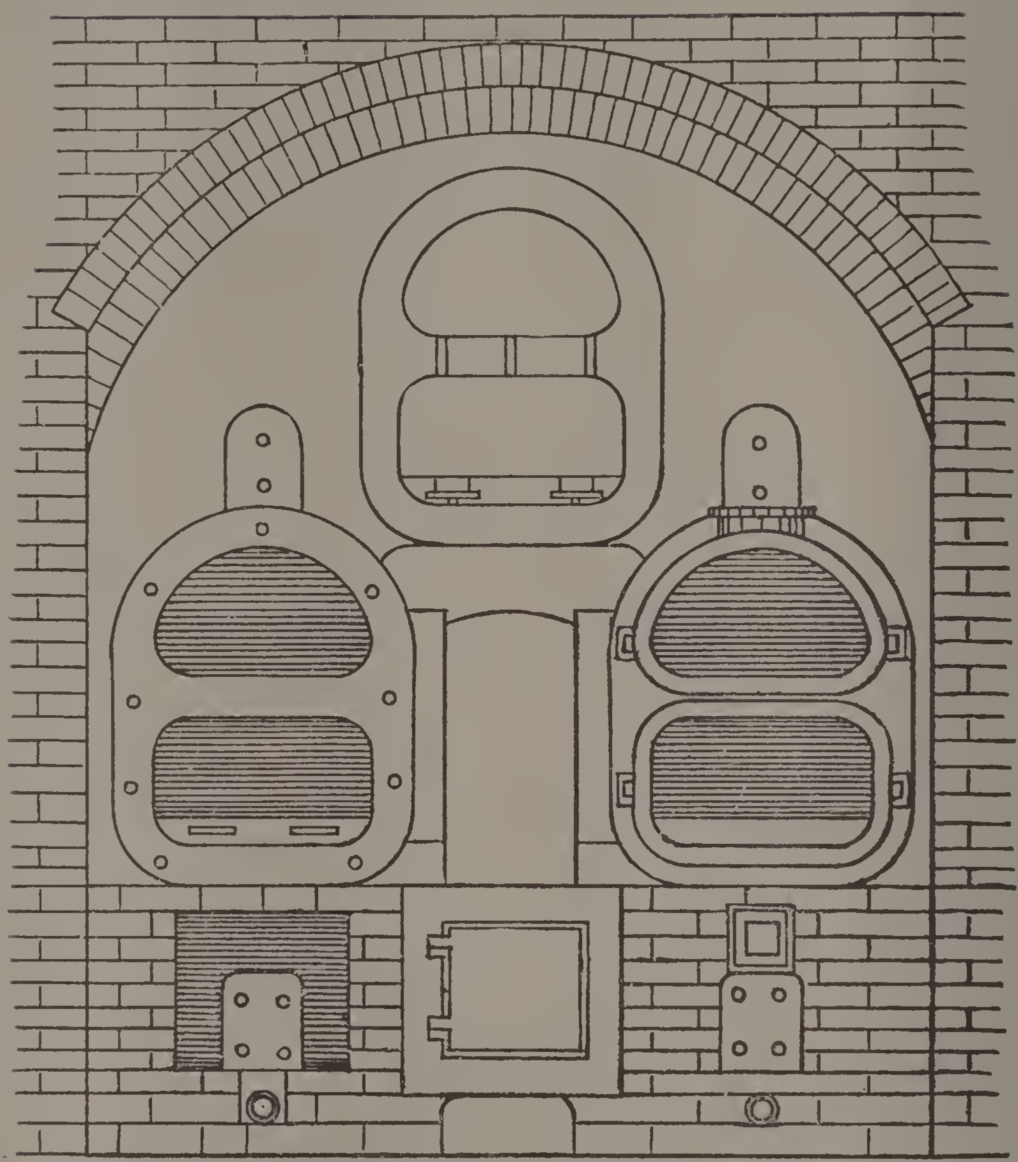
The fuel used was from the city coal-gas works, rosin for hydro-carbon and charcoal of oak and maple for carbon in retorts. Cost of materials and labor, twenty-eight to thirty cents per 1,000 cubic feet. The temperature and heat contraction of retort made the cost much greater, and defeated economy.

Yours truly,

(SIGNED) S. LLOYD WIEGAND.

Appendix E. (*1*)

G. M. Harris.— 1871.



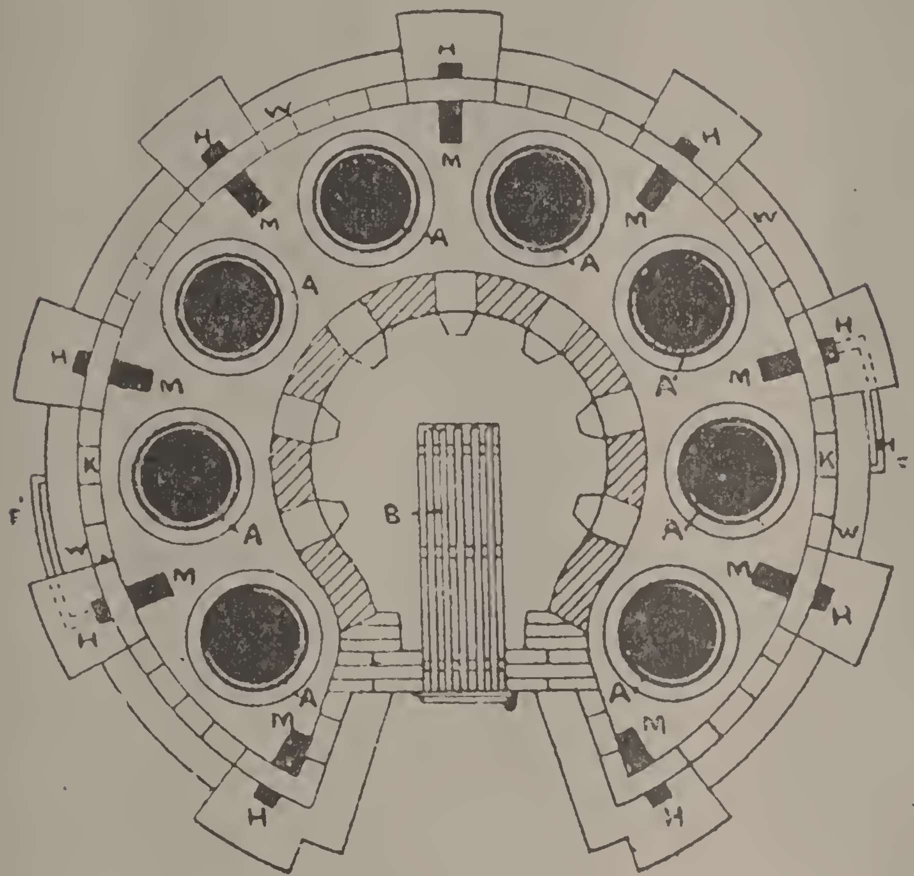
Double–Retort System.

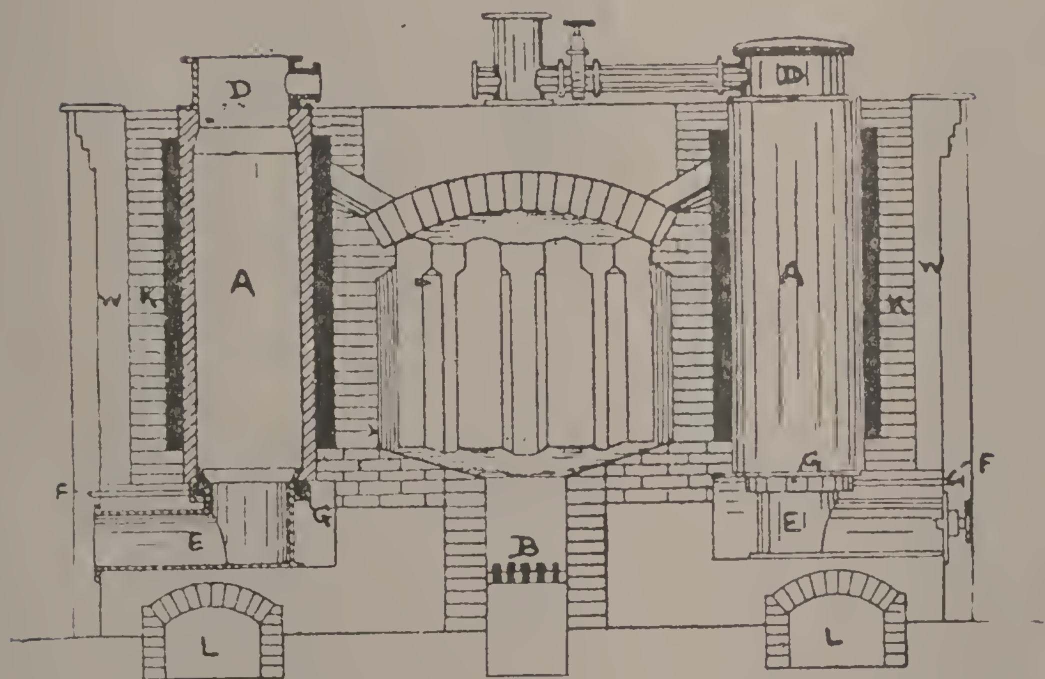
Claims.—(1.) A retort made of fire-clay, or other suitable material, the form of which is produced by the combination of two retorts into one double retort, consisting of an upper and lower chamber, each of suitable size, the division or partition between said chambers being perforated with a number of holes about one-half inch in diameter, more or less.

(2.) A combination of a lower chamber, containing a false bottom of perforated tile, in connection with the upper chamber having a perforated bottom or septum.

Appendix E. (2)

G. M. Harris and Horatio G. Allen.—1872.





A, *A*—Retorts.

B—Furnace of same.

D—Top Mouth-Pieces of same.

E—Bottom Mouth-Pieces of same.

F, *F*—Steam Pipes.

G, *G*—Steam Distributors.

H, *H*—Passages in Furnace—Wall for Superheating Steam.

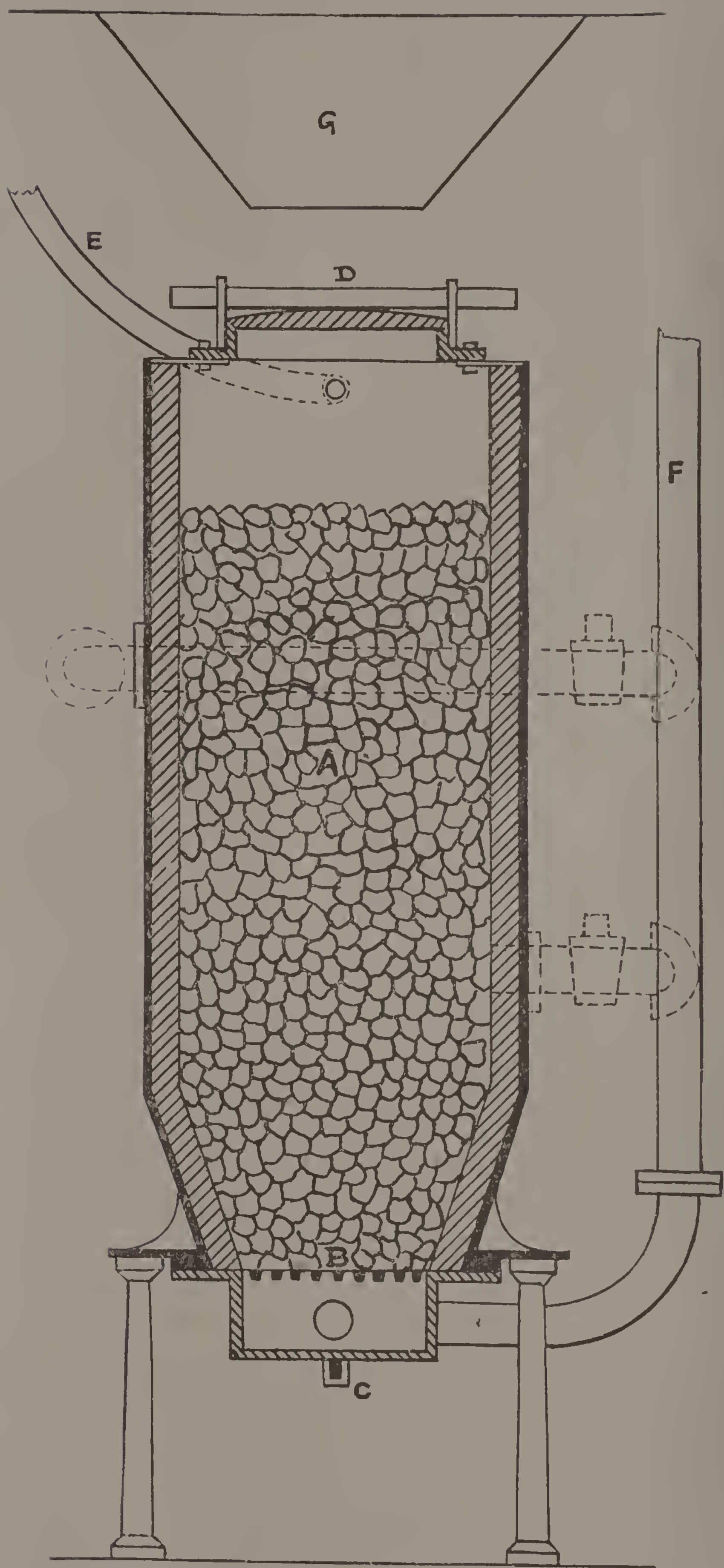
K, *K*—Fire-Brick Wall.

L, *L*—Main Flues.

M, *M*—Circularly-Arranged Flues.

Appendix F.

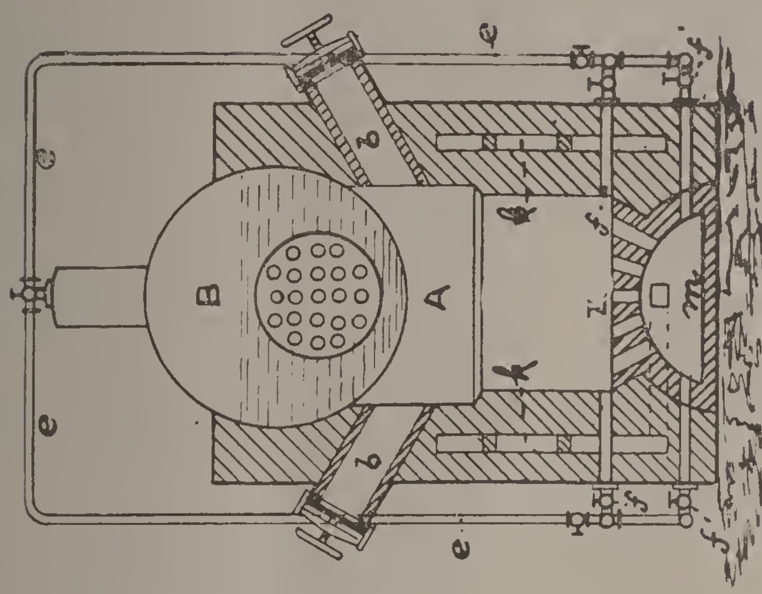
George Lowe.—1831.

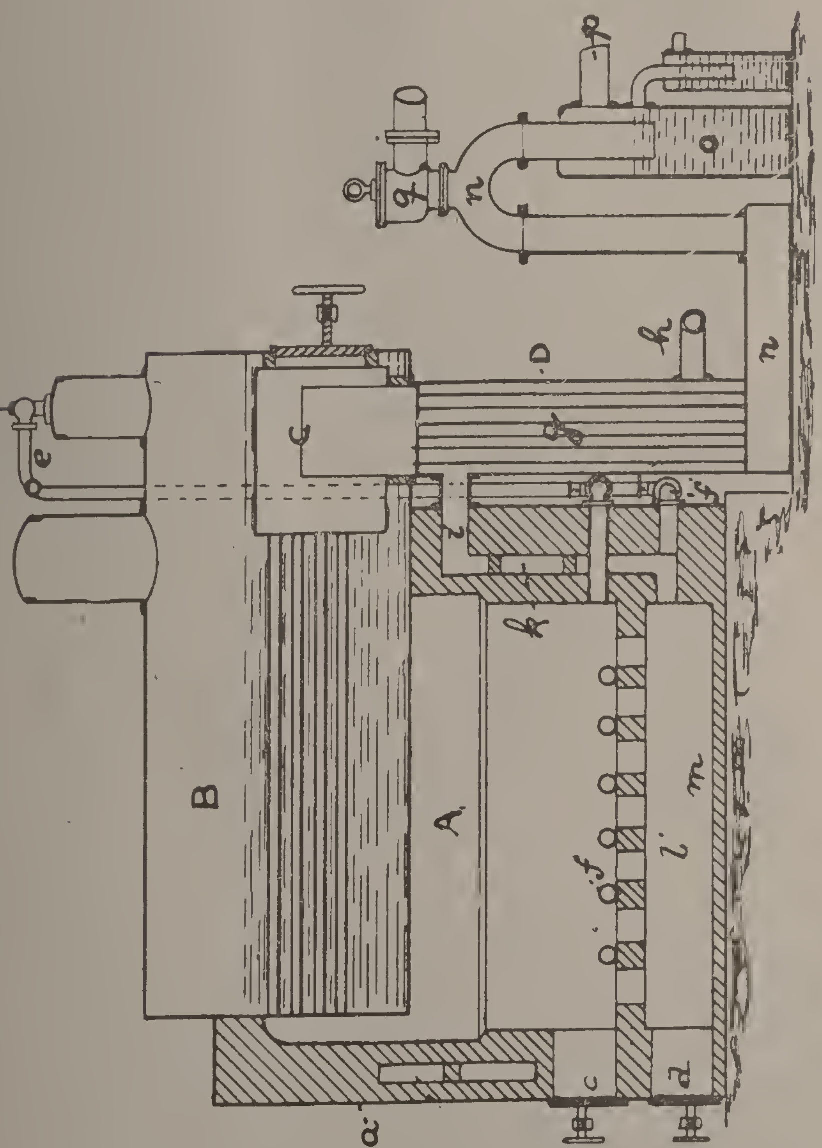


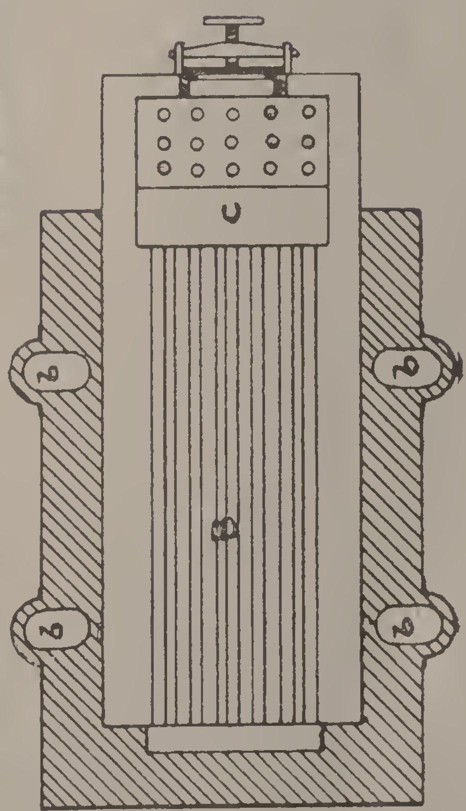
A—Generator.
B—Fire-Grate.
C, *D*—Covers.
E—Induction Pipe.
F—Eduction Pipe.
G—Hopper.

Appendix G.

John and Thos. N. Kirkham.—1852.







A—Generator.
B—Boiler.
C—Smoke-Box.
D—Blast Heater.
h—Blast Pipe.
k—Blast Heating Flues.
L—Blast Nozzle.
l'—Grate Arch.
a—Casing of Generator.

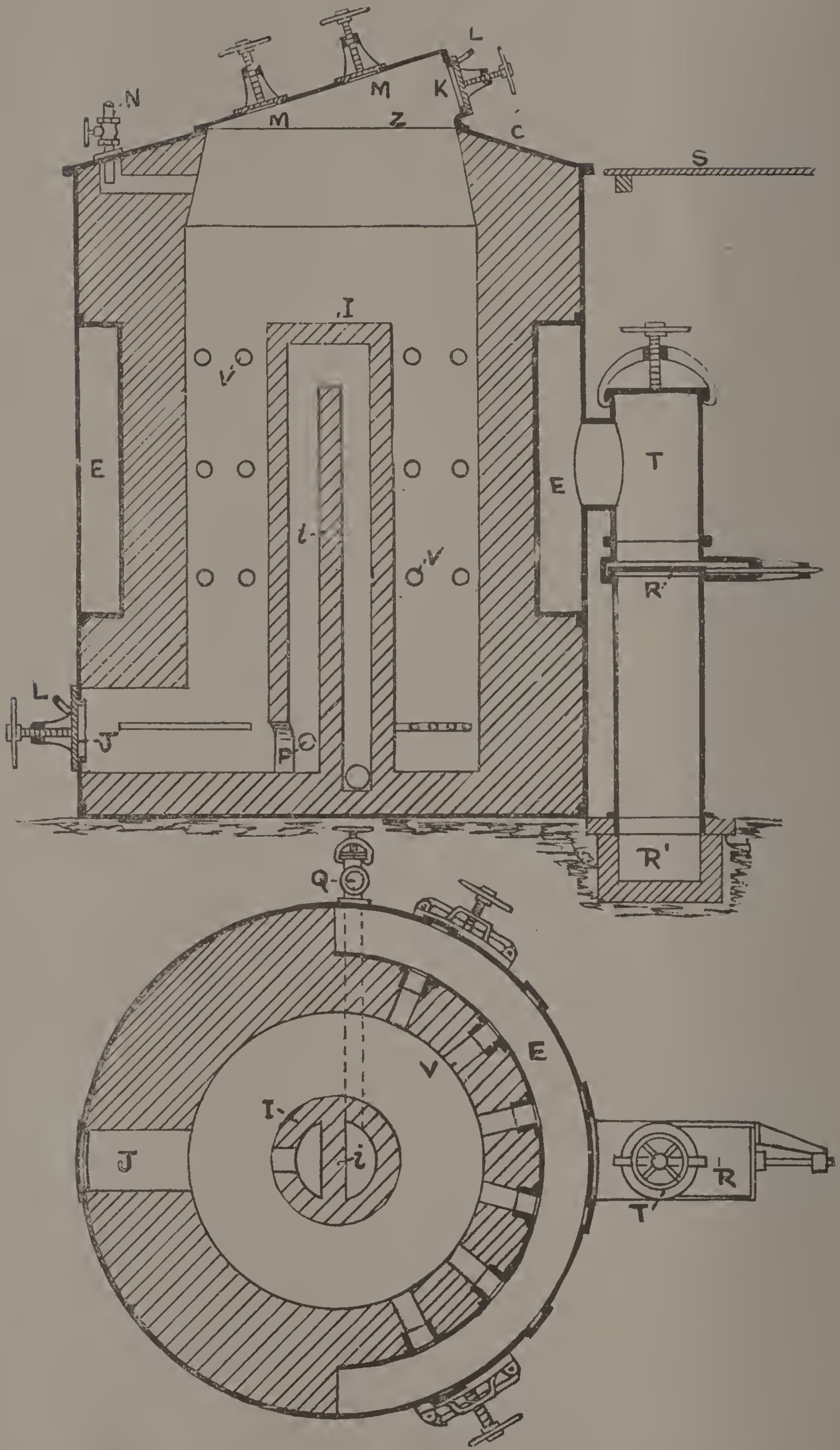
b—Charging Doors.
c, d—Cleaning Doors.
e, f, f'—Steam Pipes.

g—Blast-Heating Tubes.
n, p—Gas Main.
o—Seal.

q—Escape Valve.

Appendix H.

Fages' Gazogène.—1860.



E—Annular Blast Passage.
I—Cylinder of Fire-Clay.
i—Partition in same.
V—Blast Tuyeres.
J—Cleaning Doors.
S—Charging Platform.
K—Charging Door.
L—Handle for same.
M—Cleaning Doors.
N, *P*—Steam Pipe.
Q—Gas Main.
T—Blast Pipe.
R—Blast Valve.
R'—Blast Flue.

Appendix I.

C. W. & F. SIEMENS' IMPROVEMENTS IN FURNACES. ABSTRACT B. P., No. 972. 1863.

"Our invention consists of treating coal or other carbonaceous matter for its conversion into coke and combustible gases, either for heating or for illuminating purposes, by means of furnaces of such peculiar construction that not only is the separation of the gaseous from the solid or carbonaceous constituents of the coal, and in some cases the subsequent total conversion of its carbonaceous constituents into combustible gases, effected in a continuous manner without losing either the combustible gases evolved, or the heat residing on the coke while in a state of incandescence; but also the separation of the gaseous constituents is effected with such uniformity, and at such constant temperature, that the coal or other material operated upon, is converted into gases of considerable heating and even illuminating powers, and into coke of superior hardness and value to that produced in the ordinary gas retorts or breeze ovens; in addition to which, substances such as wood, lignite, peat and poor coal may also be made available for the production of comparatively rich combustible and illuminating gases.

"Our invention also consists in so arranging our apparatus that those gases and vapors which are usually formed when the process of distillation is carried on at the temperature heretofore employed, such as light carburetted hydrogen and olefiant gas, the vapor of tar, ammonia, carbonic acid, and others, become decomposed and reformed under the influence of a white heat into another class of carburetted hydrogens of great value for illuminating and heating purposes, such as acethylene, propylene, and analogous compounds.

"In carrying the above described general principles of our invention into practice, various modifications in the form and arrangement of the furnace may be adopted, according to the purpose to which the products are to be applied. On the accompanying drawing are shown those arrangements which we prefer to employ.

"*Figs. 1, 2* and *3*, show an arrangement of our improved furnace in which the coal or carbonaceous matter is converted into combustible gases and coke. *Fig. 1* shows a sectional elevation on line *X, X, Fig. 2*; *Fig. 2* shows a sectional plan on line *Y, Y, Fig. 1*; and *Fig. 3* shows a section on line *Z, Z, Fig. 2*. The same letters of reference indicate the same parts on each of these figures, as also in the figures representing other arrangements."

(*Fig. 1* only is shown herewith, being sufficiently explanatory without the others.—Com.)

"*A* is a vertical chamber or retort, built of fire-brick, and made of considerable depth in proportion to its breadth. At the top, the chamber is provided with a hopper *B*, through which the coal or combustible matter employed is introduced at short intervals, and which hopper is closed at the top by means of the cover *C*, dipping into the trough *b* filled with water, thus forming a hydraulic joint, and preventing the escape of the gases. In order also to prevent the escape of the gases, when the cover *C* is removed for the

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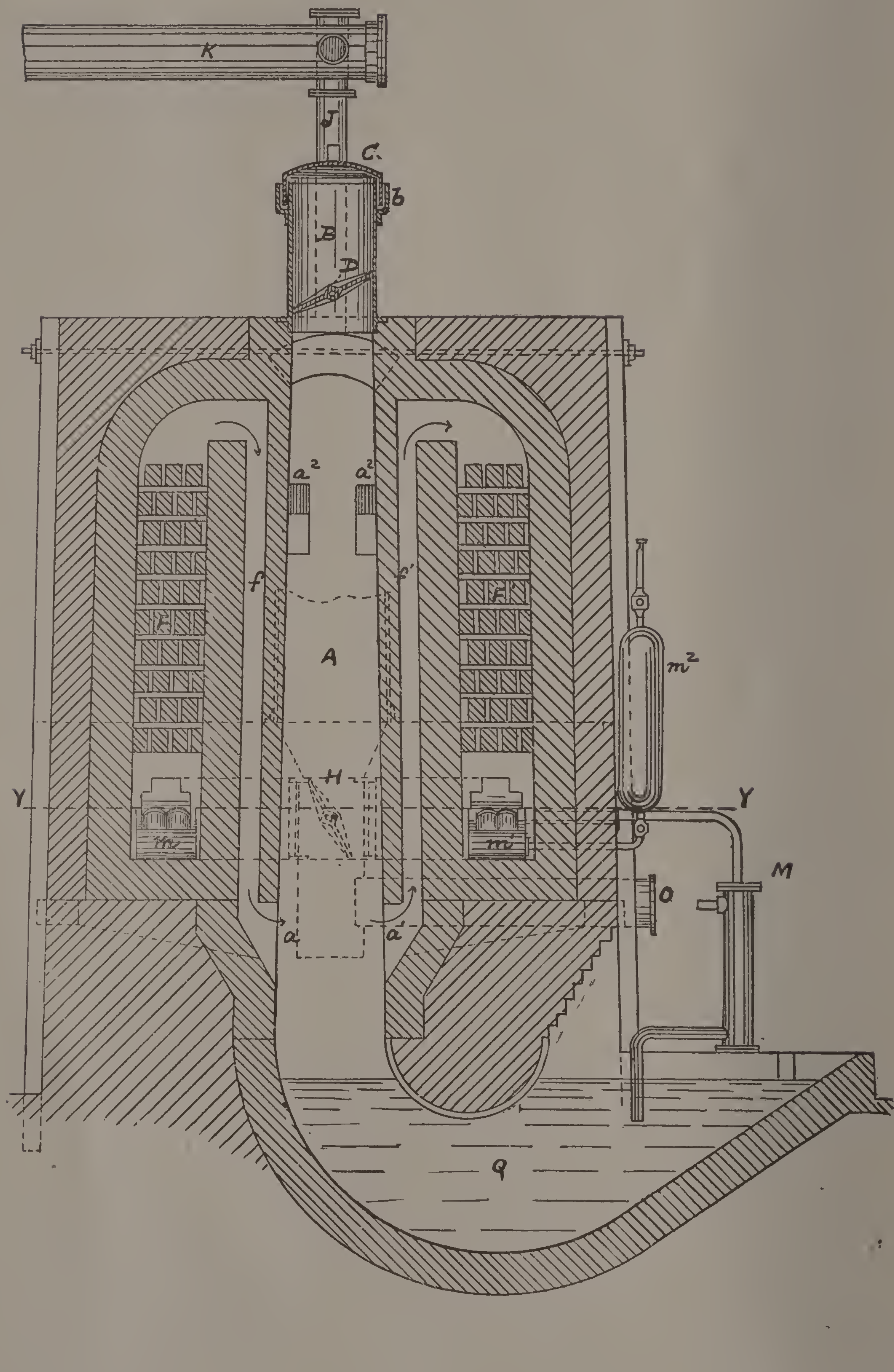
Appendix I.

C. W. and F. Siemens' Improvement in Furnaces.—1863.



purpose of filling in the coal, a valve or flap *D* is provided, which is closed when the cover *C* is removed, and opened when the same is replaced. The sides of the chamber or retort *A* are made to widen out somewhat towards the lower end, so as to facilitate the gradual passage downwards of the coal or carbonaceous matter at the bottom. The chamber or retort is formed into a shallow basin *Q*, containing water, and an opening is provided at the side below the water line, as shown, for withdrawing the coke from time to time without admitting atmospheric air into the chamber or retort. On each side of the chamber or retort *A* are formed two generators, *F*, F^1, or chambers filled with loosely piled fire-brick or other refractory materials. These "regenerators" communicate, through a number of small passages, *f*, *f*, f^1, f^1 (which also constitute a part of the regenerators) and openings *a*, a^1, with the lower part of the chamber *a*, and they are also made to communicate by means of the passages *G*, G^1, and the reversing damper *H*, alternately with the pipe *P* for conducting away the combustible gases, and with the external atmosphere through the pipe *O*. The current of the air and gases through the furnace is induced in this case by a steam jet *M*, the steam being produced in a series of water pipes, *m*, m^1, arranged in the lower part of the regenerators, and supplied with water by the feed apparatus m^2, or from an ordinary steam boiler.

"Flues * * * * are formed in the end walls of the chamber or retort *A*, communicating with the upper part of the latter by means of the openings a^2, a^2, for the purpose of conducting away the gases generated in the upper part of the chamber; these passages * * * * are made to communicate by means of pipes, either with a separate gas pipe *K*, or with the same gas pipe into which the lower gases pass.

"The action of this furnace takes place in the following manner: In commencing operations, the chamber or retort *A* is firstly filled with coke to the height of the openings *a*, a^1; fuel in a state of incandescence is thereupon introduced, and upon this is thrown fresh fuel until the chamber is full. A current of air and steam induced by the steam jet *M*, or by a jet of air only, or of oxygen with or without steam, now enter, say, through the generator *F*, and passing down the passages *f*, *f*, enters the chamber *A*, through the openings *a*, *a*, in the divided current. Here the air and steam are made to transverse the mass of incandescent fuel towards the apertures a^1, a^1, and in doing so they become converted into carbonic oxide and hydrogen, which, if the temperature be sufficiently high, again combine to form the rich combustible gases before alluded to. These pass through the apertures a^1, a^1, into the passages f^1, f^1, and down through the regenerator F^1, imparting to these the greater portion of their heat, and depositing in the same particles of uncombined carbon or soot, before entering the gas channel through the passage G^1 and valve *H*. By the withdrawal of coke from the bottom, and the introduction of fresh coal or carbonaceous matter through the hopper *B* at short intervals, the coal passes slowly down through the chamber or retort *A*, and fresh portions of the same are thus continually brought into the intense heat at *a*, a^1, whilst the coke or residuum of the carbonaceous matter passes slowly down into the basin *Q*, whence it is removed.

"When the combustible gases have passed through the chambers f, f^1, and the regenerator F^1, for a sufficient length of time for the same to have become highly heated, the direction of the current is changed by means of the valve or reversing damper H, and atmospheric air together with steam now enters the chamber or retort A, through the generator F^1, and passages f^1, f^1, taking up the heat therefrom, that has been previously absorbed from the combustible gases passing through in the reverse direction, as also burning the soot that was deposited, and, on traversing the mass of highly heated fuel, the rich combustible gases that are thereby formed, as before mentioned, are now made to pass through the apertures a, a, passages f, f, and regenerator F into the gas pipe P. At the same time as the coal or carbonaceous matter in the upper part of the chamber or retort A is subjected to a less degree of heat than below, the ordinary hydrocarbons and other vapors are there formed, and if it be desired to employ these gases separately from the gases formed below, or to mix the same subsequently, the chamber A, is provided with the flues and apertures a^2, a^2, as shown, through which these upper gases are conducted away into the gas pipes J and K. If, however, it be desired not to produce any tars or oils, but to convert the whole of the gases and vapors evolved into the rich combustible gases produced at a more elevated temperature, then the apertures a^2, a^2, and passages I, I, are dispensed with, and the whole of the gases or vapors formed in the upper part of the chamber are made to pass down through the apertures a, a^1. The coke descending into the water below in a heated condition, causes a certain evaporation, and the steam so formed, in ascending through the column of incandescent carbon, is decomposed, forming hydrogen and carbonic oxide, which combustible gases pass away with the rest. If the heat be carried to whiteness, which is accomplished by withdrawing the coke slowly, a combination will take place between the carbonic oxide formed below and the carburetted hydrogen formed above the exits a, a^1, and rich illuminating gases, such as acetylene, propylene, and analogous compounds are produced. *If these are intended to be used for purposes of illumination, the presence of nitrogen should be avoided, and pure oxygen and vapor be introduced at M.*" (Italics are the committee's.)

Appendix J.

(COPY.)

UNITED STATES PATENT OFFICE.

THADDEUS S. C. LOWE, OF NORRISTOWN, PENNSYLVANIA.

Improvement in Processes of and Apparatus for the Manufacture of Illuminating or Heating Gas.

Specification forming part of Letters-Patent No. **167,847**, dated September 21, 1875; application filed March 10, 1875.

To all whom it may concern:

Be it known that I, THADDEUS S. C. LOWE, of Norristown, Montgomery county, Pennsylvania, have invented an Improvement in Processes of and Apparatus for Producing and Using Hydrocarbon and other Gas for Heating and Illuminating Purposes, and other purposes, of which the following is a specification:

In the annexed drawings, which form a part of this specification, Figure 1 represents a vertical section of the complete apparatus, and Fig. 2 a plan of the same.

a is the primary gas generator, which consists of a casing, *b*, made of boiler iron, or other suitable material, and lined with fire-bricks *c*, or other suitable refractory materials. *d* is a superheater, for preparing steam for decomposition. This also consists of a casing of iron or other suitable material lined with fire-bricks or other suitable refractory materials *e*, the inclosed space being filled with loosely-laid fire-bricks, or other suitable refractory materials, resting on a perforated arch, *f*, of like materials. At the bottom of the superheater *d* is a combustion-chamber, *g*. *h* is a tight-fitting valve, to be raised or lowered at pleasure. *i* is a heat-restorer, which forms the stack for carrying off the products of combustion. This consists of an ordinary iron stack of increased dimension, with heads *j* at top and bottom, in which heads are inserted ordinary boiler-tubes. *k* is a tube through which there is forced into the stack *i* atmospheric air, which circulates around the tubes in said stack, and issues out at the lower end of the stack in a heated condition, thence passing through tube *l* to support combustion in generater *a*, and in the combustion-chamber *g* of the superheater *d*. *m* is an elevated tank for holding petroleum or other hydrocarbon oils. The tank *m* is supported by a column, (not shown,) or in any convenient manner. *n* is a hopper, provided with a closely-fitting bell or cone valve, *o*, and also a closely-fitting lid, *p*. *q* is a tube for conveying gas from generator *a* to the boiler *r*, which is an upright tubular boiler, with chambers *s* and *t* at top and bottom, respectively. *u* is a tube for conveying gases from chamber *t* to the washer *v*. *w* is a diaphragm, forming an incline plane in the washer *v*. This inclined plane should be rough or corrugated on its under side. *x* is a tube for conveying gases from washer *v*. *y* is an ordinary gas-scrubber, filled with coke or

Appendix J.

Lowe.—1875.

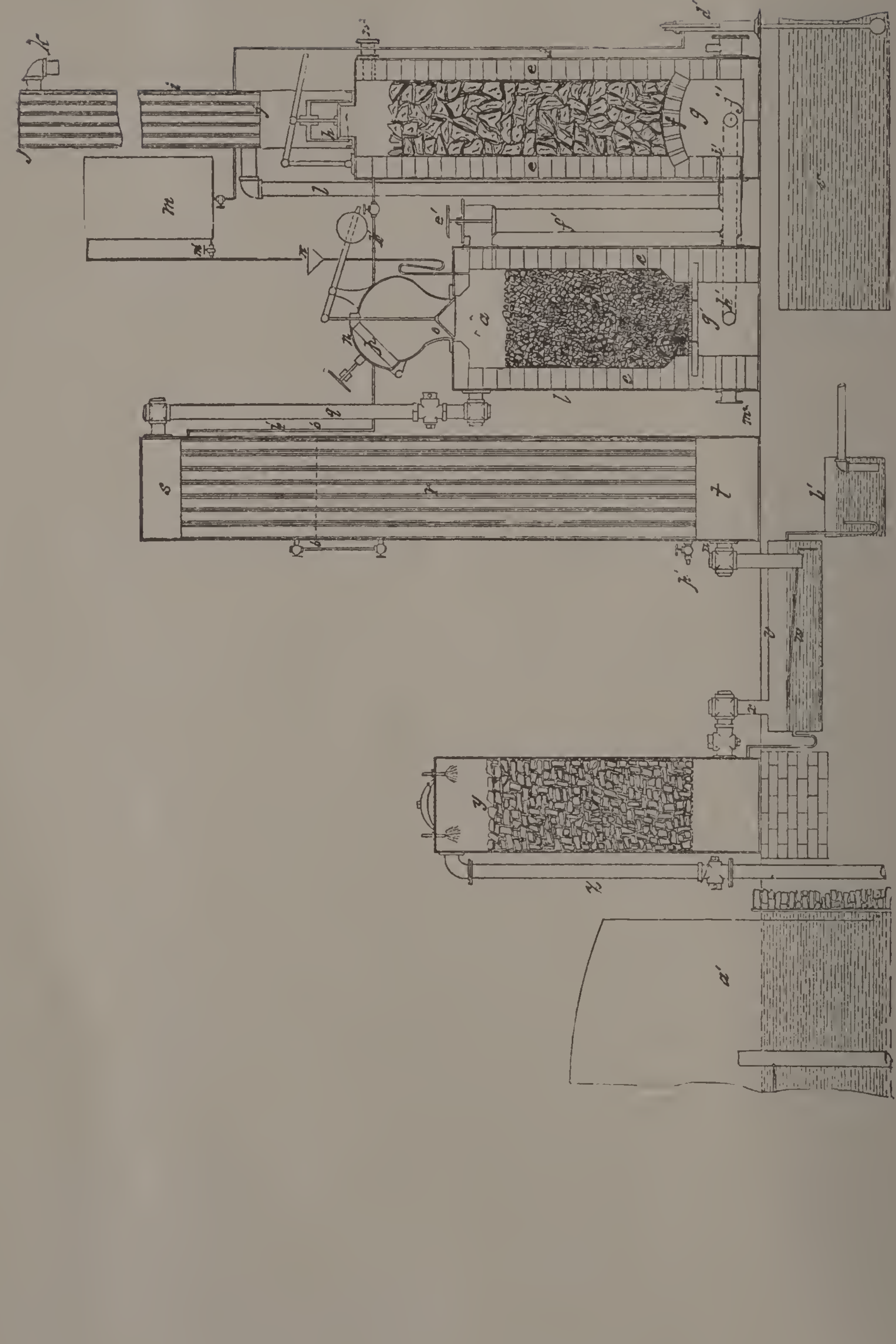


FIG. 1. Vertical Sectional View.

Appendix J.

Lowe.—1875.

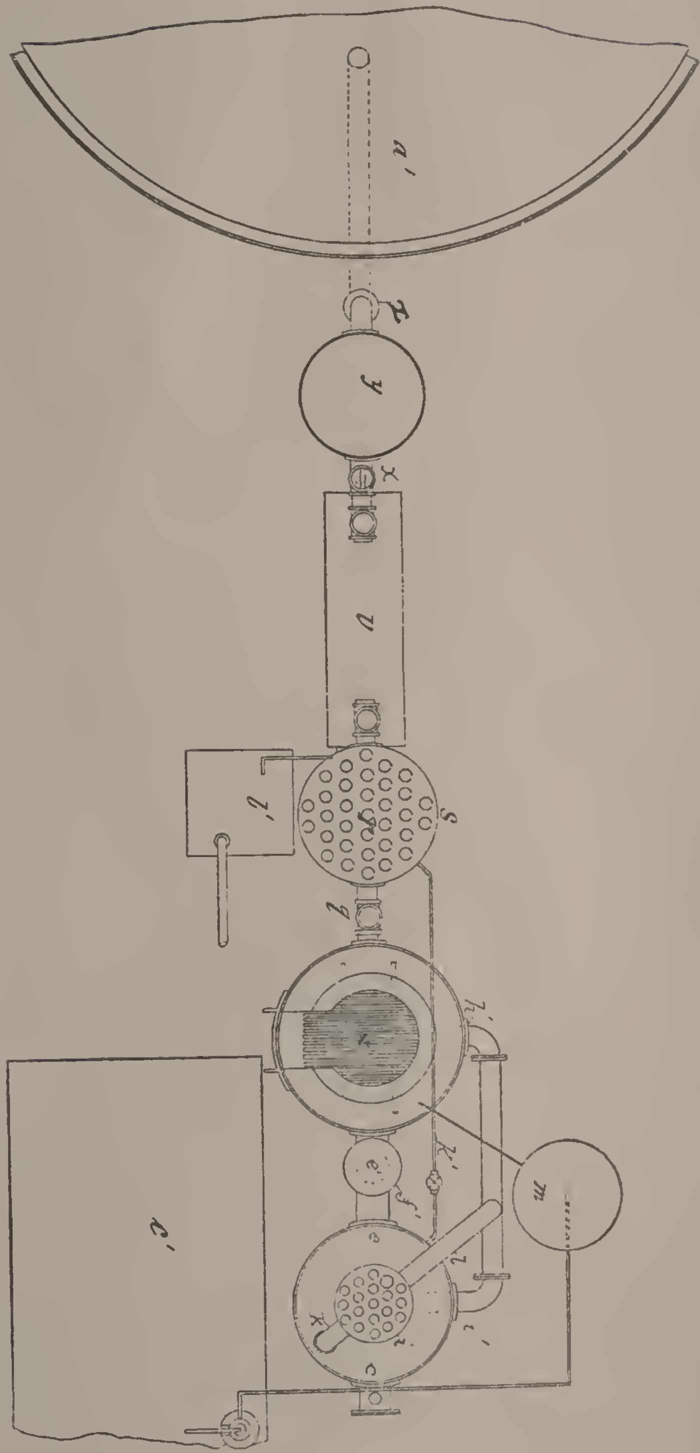


FIG. 2. Plan.

other suitable materials. *z* is a tube for conveying gases into holder *a′*, or other points of storage, or directly to any place of consumption. *b′* is a well for catching condensed oils or tar, should any exist after leaving the generator. *c′* is a tank for holding petroleum or other hydrocarbon oils, and *d′* is a pump for forcing the same, as required, into the elevated tank *m*. *e′* is a closely-fitting valve, to be raised or lowered at pleasure for regulating the flow of carbonic oxide through the pipe *f′* into the combustion-chamber *g*. The generator *a* is also provided with a closely-fitting door, (not shown in the drawing,) communicating with the ash-pit *g′*.

When it is desired to put this apparatus into operation, I build a fire on the grate-bars in generator *a*, the valves *e′* and *h* being raised to allow of the free escape of the products of combustion through the open brick-work in superheater *d*, and up through the tubes in the heat-restoring stack *i*.

I now gradually introduce into generator *a* any desired solid carbonaceous substances, preferring either anthracite or bituminous coals, beside which, however, may be mentioned any kind of wood, all kinds of woody rubbish, finely-cut straw, coal-dust or slack, asphaltum, &c.

In the meantime a fan-blower or other suitable apparatus is caused to force air through the tube *k* into the heat-restorer *i*, from which a sufficient quantity of warmed or heated air is admitted through the tubes *l* and *h′*, to cause moderate combustion on the grate-bars of the gas-generator *a*. As the thickness of fuel increases in generator *a*, and while it is being brought into an incandescent state, the carbonic acid which is caused by the union of oxygen and carbon, at the bottom of the generator, while passing up through the thickness of incandescent fuel, becomes recarbonized, and is thus converted into carbonic oxide. This highly-inflammable gas, in union with the sulphur of the coal and other impurities thrown off by the heat, leaves the generator *a* through the valve *e′*, and is discharged into the combustion-chamber *g* through the opening *i′*. Air at the same time being admitted through tube *j′* into said chamber *g*, a flame ensues, producing an intense heat, the flame and hot products of combustion passing up through the openings in the arch *f*, and heating to bright redness the entire mass of inclosed open brick-work from bottom to top, the combustion-chamber *g* becoming white hot. In the meantime considerable heat, which ascends through the open tubes of the superheater *d*, being carried in the products of combustion, is absorbed by the air, which is forced in an opposite direction down the stack around the tubes, and is returned to the lower ends of the heated chambers *g* and *g′* for supporting combustion in the generator *a* and the superheater *d*, thus lessening the length of time and amount of fuel required to produce the necessary heat in the different chambers. After the mass of fuel, several feet in thickness, in the generator *a* has become thoroughly incandescent, the superheater *d* will also have become highly heated by the combustion of the (otherwise) waste gases passing from the generator *a*. I now shut off the air from both chambers *g* and *g′* and close the valves *e* and *h*, and admit steam (preferably superheated) into the top of the superheater *d* through tube *k′* from boiler *r*. This steam passing down through the highly-heated brick-work, becomes intensely heated, and is thus conveyed

into ash-pit g', through opening h' where, coming into contact with carbon, also highly heated, the decomposition of the steam immediately takes place, liberating the hydrogen, and producing a proportionate quantity of carbonic acid. This latter gas, however, is immediately changed to carbonic oxide by recarbonization while passing up through the thick mass of incandescent fuel, the decomposition being materially aided by the high degree of heat acquired by the steam in the superheater.

At the same time that I thus admit steam into the superheater I also admit petroleum or other hydrocarbon oils in regulated quantities from tank m through cock m', into funnel n', whence, passing in through a pipe, it drops directly onto the hot coals in generator a. Here the liquid hydrocarbon is immediately volatilized into a thick vapor, and at this point the highly-heated hydrogen, continually emerging from the top of the coals, instantly, and before having time to lose in heat, intermingles with and thoroughly permeates every particle of the volatile carbon, which has the effect, by this intense heat, to separate and so sub-divide the particles or globules of carbon, and at the same time surround them so uniformly with the proper proportion of hydrogen that the particles of carbon, not being able to come in contact with each other, are rendered entirely non-condensable, as has been proven by numerous experiments and long practical experience. These mixed gases, in their highly-heated condition, are now continually being carried off through tube q and enter chamber s at the top end of boiler r, where they pass down through the numerous tubes contained in said boiler, and have the effect to superheat the steam in the upper part of the boiler, as well as to rapidly generate steam at o', below the water-line, and still farther down to heat the water as it is gradually pumped into the boiler through pipe p'. The gases, now considerably cooled, leave the tubes and enter chamber t, and thence, through tube u, into the wash-box v, where they pass under the inclined plane w, under water, in which any soot, dust, or other impurity is deposited. From the washer the gas next enters the lower end of scrubber y, and, after passing up through the contents thereof, is conveyed through the tube z to holder a' or other points of storage, or directly to any place of consumption.

While generating gas, as above described, a test-burner will readily indicate the quality or candle-power of the gas being produced, and the requisite carbon or hydrogen can easily be regulated by regulating the quantity of oil admitted to the generator a or of steam to the superheater d.

After a time, and when a large quantity of gas has been produced and stored, the heat will be so much reduced in both the superheater d and the generator a that the steam will no longer decompose, (although both chambers will still retain a dull-red heat,) the non-decomposition of the steam being at once detected by the smokiness of the flame at the test-burner, which, for want of hydrogen, gives a thick, dark-red smoky flame through an ordinary four or five feet burner. Such gas is known as "petroleum gas," and condenses rapidly in consequence of not being mixed with a proper proportion of hydrogen in the manner above described.

Whenever it is desired to restore the heat to the fuel in the generator a and the superheater d, the hydrocarbon oil and steam are both stopped off,

and valves c' and h are opened, and atmospheric air is again forced into ash-pit g, and combustion-chamber g', as before described, and now a few minutes' time suffices to bring both chambers to the required heat, after which a large amount of hydrocarbon gas is again produced as before.

When a steady flow of gas is desirable, (as in the cases where small holders are employed,) I employ two sets or more of generators, according to the requirements.

The gas from all the generators may be passed through and caused to generate steam in one boiler, r; so, also, one heat-restorer, i, can be made to carry off the hot products of combustion from all the generators and superheaters, and thus serve to heat the air which is to support combustion in each, thus accomplishing the heating with much rapidity and economy, as above set forth.

The forms of apparatus which may be used in carrying out my above-described processes are various, and I have prepared many drawings of modified forms of apparatus for carrying out said process; but I prefer the form shown, it being in every respect simple and easy of management.

Instead of employing oil in the carbonizing process, as above described, other substances containing volatile carbon may be employed, such as rich bituminous coal, rosin, cotton-seed, ordinary coal-tar, asphaltum, fats of all kinds, residuum from oil-refineries, etc. Care, however, should be taken when using any kind of solid carbon that the same is evenly spread on the top surface of the heated fuel or material in the generator a, in such a manner that the hot gases, while emerging from the top of said hot fuel, will come in contact with such solid or lumpy carbon, and thereby assist in its volatilization.

In case of using bituminous coal, it would be desirable to use some additional volatile carbon oil, to add to the hydrogen being generated from the steam.

If impure carbons are used for carbonizing the hydrogen, the usual purifiers will be necessary; but when petroleum and other pure carbons are employed, a purifier is not required.

In many cases it will be found advantageous to admit the steam (preferably highly heated) through pipe m^2 at the bottom of generator a, causing it to pass up through the incandescent coals and mingle with the carbon gas in the top of the generator, as before described, and then to pass the mixed mass through connecting-flue f' to the bottom of superheater d, and up through the mass of heated brick-work therein contained, and to be discharged through opening n^2 at the top of superheater d, from which opening the gases may be conveyed to the washer v, either directly or after having been previously passed through the boiler r, for the purpose of utilizing its heat in the generation of steam, or after having been employed for superheating steam or air, or both.

The principal advantage gained by passing the mass of gases from generator a through the highly-heated fire-bricks in the superheater d is a more thorough decomposition of the elements which, having been passed up through the incandescent coal in the generator for too long a time, might

contain considerable undecomposed vapor, which would be converted into a fixed gas by being subjected to a higher heat, such as the superheater contains.

When it is desired to superheat the steam preparatory to its decomposition, and at the same time carry on the process of more permanently fixing the mixed gases evolved in the generator, it is necessary to use, in connection with the generator, two of the chambers described as superheater *d*—to wit, one for the superheating of the steam, and the other for the fixing of the gases, both chambers being similar in construction, and similarly arranged with respect to the generator, and similarly heated by direct internal combustion of a portion of the gases from generator *a*, and, in this case, the mixed gases from the generator, instead of being led off to and through the tubes of boiler *r*, as described, or, instead of being led off from the generator directly to the washer, are first passed through the additional chamber or superheater last above referred to.

The heat-restorer *i* may, instead of serving to heat the air-blast, as before described, be used as a boiler for generating steam, and may either remain in its present position or be set adjacent to the superheater, where the hot products of combustion may be conveyed to it in the proper manner.

In cases where gas extremely rich in carbon is desired, the same will be best produced by omitting the steam and generating the gas from oils alone, using the generator *a* either alone or in conjunction with the superheater.

I claim—

1. For the manufacture of illuminating and heating gas, the process which consists of dropping or otherwise admitting in limited quantities, continuously or intermittently, hydrocarbon oils or other carbonaceous substances, liquid or solid, onto the top of a thick mass of coal or other carbonaceous substance, in a state of incandescence, in a close chamber previously heated by direct internal combustion, with or without the introduction of steam, and then, for the purpose of superheating and fixing the gases of said chamber, passing them from said chamber into and through a second chamber, which also has been previously heated by direct internal combustion, substantially as set forth.

2. The process for producing an illuminating gas, which consists of superheating steam, by passing it through a chamber previously heated by direct internal combustion, then causing said steam to pass through a mass of coal or other carbonaceous substance, in a state of incandescence, in a close generating-chamber, to decompose the steam, and afterward, for the purpose of still further heating the gases of said generating-chamber, and thereby producing a more fixed gas, passing the gases from said generating-chamber into and through another superheating-chamber, which has been previously heated by direct internal combustion, substantially as set forth.

3. The combination of the generator *a*, superheater *d*, the heat-restorer *i*, and means for forcing air through the pipe *k*, around the tubes of the heat-restorer *i*, through pipes *l*, *h'*, and *j'*, into the chamber *g*, for generating and securing intense combustion in said chamber *g*, substantially as set forth.

4. The combination of the generator *a*, superheater *d*, heat-restorer *i*, elevated oil-tank *m*, the upright tubular boiler *r*, with their several connecting-pipes and other appurtenant parts, as described, constituting apparatus for rapidly evolving illuminating-gas, and, fixing the same in its gaseous condition, substantially as set forth.

5. The combination of the generator *a*, superheater *d*, heat-restorer *i*, elevated oil-tank *m*, upright tubular boiler *r*, wash-box *v*, scrubber *y*, with their several connecting-pipes and other appurtenant parts, as described, constituting apparatus for rapidly evolving illuminating and heating gas, fixing the same in its gaseous condition, and purifying the same preparatory to storage or immediate use, substantially as set forth.

T. S. C. LOWE.

Witnesses:

R. B. Sanderson,
Thos. A. Burtt.

Appendix K.

CITIES AND TOWNS USING WATER-GAS PROCESSES.

Arizona.	
Tucson, . . .	Lowe.
California.	
Oakland, . . .	Lowe.
San Francisco, . .	"
San José, . . .	"
Colorado.	
Georgetown, . .	Hanlon.
Connecticut.	
Danbury, . . .	Edgerton.
Middletown, . .	Lowe.
New Haven, .	Hanlon-Ledley.
Wallingford, . .	Edgerton.
Waterbury, . .	Lowe.
District of Columbia.	
Washington, .	Lowe, Granger.
Florida.	
Pensacola, . .	Edgerton.
St. Augustine, . .	Lowe.
Georgia.	
Atlanta, . . .	Lowe.
Savannah, . . .	"
Illinois.	
Bloomington, . .	Lowe.
Chicago, .	Lowe, Springer, Granger, Flannery.
Decatur, . . .	Lowe.
Lake, . . .	Granger.
Peoria, . . .	Lowe.
Pullman, . . .	"
Illinois.	
Quincy, . . .	Granger.
Sterling, . . .	Lowe.
Indiana.	
Indianapolis, . .	Lowe.
Greensburgh, . .	"
Kokomo, . . .	"
Iowa.	
Burlington, . .	Granger.
Kansas.	
Newton, . . .	Springer.
Wyandotte, . .	Lowe.
Kentucky.	
Frankfort, . . .	Lowe.
Lexington, . .	"
Louisville, . .	"
Newport, . . .	"
Louisiana.	
New Orleans, .	Oil and Lowe.
Maryland.	
Baltimore, . .	Lowe.
Frederick, . .	"
Hagerstown, . .	"
Massachusetts.	
Athol, . . .	Granger.
Charleston, . .	"
Cottage City, . .	Loomis.
Lynn, . . .	Granger.
Waltham, . .	Mackenzie.

Massachusetts.

Worcester, . . . Granger.

Michigan.

Battle Creek, . . . Lowe.
Flint, . Hanlon-Ledley.
Marshall, . . . Lowe.
Niles, . . . Springer.

Minnesota.

Duluth, . . . Flannery.

Mississippi.

Vicksburg, . . Lowe.

Missouri.

St. Louis, . . . Lowe.

Nebraska.

Omaha, . . . Lowe.

New Hampshire.

Dover, . . . Lowe.
Keene, . . . "
Laconia, . . . "

New Jersey.

Atlantic City, . . Hanlon.
Cape May, . . Lowe.
Hoboken, . . Wilkinson.
Jersey City, Lowe, Flannery, Granger.
New Brunswick, . Lowe, Granger.
Passaic, . Hanlon-Ledley.
Paterson, . . . Lowe.
Plainfield, . . . "
Trenton, . . . "
Vineland, . . Mackenzie.

New York.

Attica, . . . Lowe.
Batavia, . . . English
Binghamton, . . Granger.
Clyde, . . . Lowe.

New York.

Cohoes, . . . Granger.
Cooperstown, . . Lowe.
Coney Island, . . Granger.
Fort Plain, . . Lowe.
Garden City, . Mackenzie.
Glen Island, . . Granger.
Goshen, . . . Averill.
Haverstraw, . . Lowe.
Middletown, . . Averill.
Newburg, . . Lowe.
New York City, Tessié du Motay, Jermanowski, Wilkinson.
Nyack, . . . Lowe.
Plattsburgh, . . "
Port Henry, . . "
Port Jervis, . . Granger.
Poughkeepsie, . Allen-Harris.
Rochester, . . Lowe.
Rondout, . . Allen-Harris.
Saratoga, . . . Lowe.
Staten Island, . . Flannery.
Utica, . . . Granger.
Yonkers, . Tessié du Motay, Lowe.

North Carolina.

Charlotte, . . Lowe.
Newberne, . . "

Ohio.

Elyria, . . . Lowe.
Norwalk, . . . Flannery.

Pennsylvania.

Alleghany, . . Granger.
Beaver Falls, . . Lowe.
Bethlehem, . . "
Carlisle, . . . "
Catasauqua, . . "
Chambersburg, . "

Pennsylvania.	
Columbia, . .	Lowe.
Conshohocken, . .	"
Erie, . . .	Granger.
Falls Schuylkill, .	Lowe.
Girardville, . .	"
Harrisburg, . .	"
Hazelton, . .	"
Honesdale, . .	Granger.
Huntingdon, . .	Pierson.
Lancaster, . .	Lowe.
Mauch Chunk, . .	Granger.
Middletown, . .	Flannery.
Mount Joy, . .	Lowe.
Phœnixville, . .	"
(First Lowe Works.)	
Pittston, . . .	"
Pottsville, . . .	"
Reading, . . .	"
Schuylkill Haven, .	"
Scranton, . .	"
Shippensburg, . .	"
Stroudsburgh, . .	"
Tamaqua, . . .	"
Waynesboro', . .	"
West Manayunk, .	"
Wilkesbarre,	Lowe, Granger.
Williamsport, . .	Lowe.
York, . . .	Granger.

South Carolina.	
Columbia, . .	Pierson.
Tennessee.	
Chattanooga, . .	Lowe.
Knoxville, . .	"
Texas.	
Waco, . . .	Lowe.
Vermont.	
Brattleboro, . .	Lowe.
Burlington, . .	"
Montpelier, .	Hanlon-Ledley.
Rutland, . . .	Lowe.
St. Albans, . .	Granger.
St. Johnsbury, . .	Lowe.
Virginia.	
Norfolk, . . .	Granger.
West Virginia.	
Charlestown, . .	Lowe.
Wisconsin.	
Appleton, . .	Lowe.
Canada.	
Brockville, . .	Lowe.
Guelph, . . .	"
Kingston, . . .	"
Sherbrooke, . .	Granger.
St. Hyacinthe, . .	"
Toronto, . . .	Lowe.
Cuba.	
Havana, . . .	Lowe.

[NOTE.—The committee is indebted to Mr. G. W. Graeff, Jr., editor of *Light, Heat and Power*, for many of the data in the foregoing list. Several of the processes named therein differ from that of Mr. Lowe in unessential details only, such as the disposition of the several parts of the apparatus with reference to each other, the manner of introducing oil or steam, etc.—COM.]

Appendix L.

REPORT OF THE JUDGES OF THE "NOVELTIES" EXHIBITION ON THE LOWE WATER-GAS EXHIBIT, NOVEMBER, 1885.

The exhibit of this company formed a very complete exposition of the capabilities of water-gas for heating, lighting and the generation of power. It embraced a gas works, complete for the generation of water-gas, having a capacity of 5,000 cubic feet per hour.

The adaptability of the product as a fuel was exhibited in a variety of ways. It was used exclusively in the restaurant for all the uses in cooking, baking, etc., for which solid fuel is commonly used, and by various exhibitors throughout the exhibition for heating, baking, driving gas engines, and other special uses.

For the utilization of gas for fuel purposes, the company exhibited a variety of ovens, cooking ranges, open-fire stoves, heaters, etc., of special designs.

In a suite of three rooms, occupied by this company, a very attractive display was made of the adaptability of water-gas for domestic lighting and heating. Its display embraced an open fire-place of the usual pattern, various forms of fixtures adapted for a special system of incandescent lighting (which will be treated of later), several forms of combined heating, lighting and ventilating devices, etc., etc.

The general purpose of these exhibitors was to show how, through a single line of pipe laid in the streets of cities and towns, a gas may be distributed, which will serve as an efficient and economical source from which light, heat and power may be obtained. In respect to the variety of applications shown, and the ingenuity displayed in the design of the various devices used, and the mechanical skill and tastefulness exhibited in the construction the exhibit of the company was highly commendable.

Taken collectively, it is safe to say, that, in respect to completeness and variety, it far surpassed any exposition of the capabilities of water-gas ever before attempted.

The time at the disposal of the judges has not been sufficient to

enable them to make a careful examination of the question of originality in connection with many features of this interesting exhibit.

Water-gas made by the interaction of steam and carbon at a high temperature, and composed essentially of hydrogen and carbonic oxide, has been known and employed for many years. It is only, however, of late years, that the difficulties in the way of its successful commercial introduction have been practically overcome.

Generally, the improvements that have brought about this result consist of the adoption of methods, whereby the waste of heat in the various steps of the manufacture is reduced to the minimum.

The principal portion of this waste was, formerly, the large consumption of coal required for heating the contents of the generator to the proper temperature to effect the decomposition of the steam, the heat required for the production of the steam, and the heat carried off by the water-gas after its formation.

These elements of waste have been largely reduced by the adoption of devices, whereby the products of incomplete combustion in the generator are regenerated, and caused to impart the heat derived from their subsequent combustion to such heat-storing materials, as fire-brick, etc , suitably placed in a regenerative chamber, or superheater, forming the upper portion of the generator, or connected with it, and through which the steam is caused to pass on its way to the generator.

Further, by using other portions of the waste heat, to heat the air used for blowing up the charge of coal in the generator, and to generate the steam required in the process. By these and other improvements in the construction of the apparatus employed, and in the details of the operation, the quality and quantity of water-gas produced from a ton of coal have been, respectively, considerably increased and improved, and the cost of its production so notably reduced that the problem of introducing it as a fuel for domestic and industrial purposes can no longer be considered as visionary.

It is proper to state in this place, that, with a number of the improvements above noted, and which have substantially contributed to the practical success of water-gas manufacture, the name of Thaddeus S. C. Lowe, of Norristown, is honorably associated, and a number of patents embodying the same have been issued to him, which are accessible for reference.

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The devices in the form of ovens, heaters, ranges, stoves, etc., which are embraced in the exhibit of the Lowe Manufacturing Company, are in great variety, and are admirably adapted to serve their intended purposes.

On the general question of the desirability of gaseous fuel, there can be but one opinion. It dispenses with the trouble and annoyance of hauling and carrying coal, and with the removal of dirt and ashes; it is at all times under perfect control; when not wanted it can instantly be extinguished and can instantly be made to give its maximum effect, so that, other things being equal, gaseous fuel possesses incontestable advantages over solid fuel.

Respecting the availability of water-gas for this purpose on the score of economy, the Lowe Manufacturing Company claims to produce from a ton of coal 80,000 cubic feet of water-gas, at a cost of less than ten cents per 1,000. At these figures, twenty-eight pounds of anthracite coal would yield 1,000 cubic feet.

The specific gravity of the Lowe Fuel-Gas, as determined by Dr. Ward, of the judges, is (at 62° F.) ·552 (air = 1).

The 1,000 cubic feet would, therefore, weigh 42·01 pounds. As the theoretical yield of 100 pounds of pure anthracite would be 228·22 pounds of pure gaseous products, the figures claimed to be obtained by the Lowe Manufacturing Company, would be sixty-six and two-thirds per cent. of the theoretical yield of pure carbon. This would leave but thirty-three and one-third per cent. to provide for the consumption of coal for heating the generator, for the production of steam, and the impurities of the coal.

The judges had no opportunity to actually test the question by experiment, but they feel satisfied that the company's estimate of production is too high.

In processes analogous to this in general principles, a practical yield of from 40,000 to 45,000 cubic feet has been obtained, and the judges assume the lowest quantity here named as the safer one to proceed from.

Dr. Greene, of the judges, made an analysis of the gas, taken on October 19th, with the following results:

	By Volume.	*By Weight.*
CO_2,	3·6	9·3
CO,	42·1	69·3
H,	44·5	5·2
N (by diff.),	9·8	16·2
	100·00	100·00

The theoretical calorific equivalent is:

	Composition in Dec. of one Pound.		*Calor. Equiv.*
Nitrogen, ...	0·162	×	0·0
Carbonic acid, ...	0·093	×	0·0
Carbonic oxide, ...	0·693	×	4325·4 = 2997·4
Hydrogen, ...	0·052	×	62031·6 = 3225·7
Calorific equivalent of Lowe gas in British heat units,			= 6223·1

Taking the yield of gas to be 40,000 cubic feet per ton of coal (2,240 pounds), fifty-six pounds would be sufficient to yield 1,000 cubic feet of gas, weighing, as above noted, 42·01 pounds, and having a theoretical heating effect of (42·01 × 6223 1) = 261 433 units of heat.

As, in the combustion of gaseous fuel, under favorable circumstances, the only loss is from radiation, it is fair to assume that this loss will not exceed ten per cent. This will leave of the above, 235,289 units realizable in practice.

Fifty-six pounds of coal would have a theoretical heating effect of 56 × 14,544 = 814,464 units, of which about fifty per cent. may be assumed to be realizable.

This would leave, under ordinary circumstances, 407,232 units available in practice; from which it appears, under the ordinary conditions of practice, the fuel gas will produce fifty-three per cent. of the available heating effect of the coal used in making it.

The company states that the cost of production will be less than ten cents per 1,000 cubic feet. We will take ten cents. Taking pea coal at $1.50 per ton, the fifty-six pounds will cost three and three-fourths cents, and, with the assumption of only fifty per cent. of the theoretical effect yielded, the figures would be doubled. When, therefore, solid fuel is utilized, as in ordinary steam generation, the relative cost of coal, and of the fuel-gas which may be obtained from it, under the above assumptions of cost, will be in favor of coal.

This, however, is the conclusion from assumptions, which present the most unfavorable conditions for fuel-gas. For, in practice, the cheapest grades of coal cannot be used, and the cost of coal generally used for manufacturing and domestic purposes, may be assumed to be $4.50 per ton, which would make the cost of the fifty six pounds (above employed) equal to eleven and one-quarter cents, which,

when compared with the figure of ten cents, which we have purposely taken for the Lowe Fuel-Gas, shows that the fuel-gas can compete economically with solid fuel, where the cost of distribution is neglected.

We should state here in justice to these exhibitors, that they claim to be able to produce fuel-gas considerably cheaper than ten cents per 1,000 feet.

In all the above calculations and comparisons, it should be noted that the judges have presented the case of fuel-gas in the most unfavorable light, so that the conclusions above announced may be considered as an exhibit of the lowest economical results that should be attained in practice. For, it should be stated, that in ordinary practice, especially for domestic service, very much less than fifty per cent of its thermal value, is obtained from the combustion of coal.

As, under these unfavorable assumptions, the results obtained exhibit a comparative economy in favor of fuel-gas, the friends of water-gas have every reason to be satisfied.

Much stress has been laid by certain writers upon the poisonous effects of water-gas, due to the large percentage of carbon monoxide, which it contains, and which is held to constitute a serious objection to its general introduction. This objection, the judges do not deem sufficient to warrant the condemnation of an agent which promises to serve so many useful purposes. The same objection was made to coal-gas, by those who opposed its first introduction, and with as much justification as the opponents of water-gas have at the present.

For the purpose of asphyxiation, either coal-gas or water-gas, will answer quite satisfactorily. It should be remembered, however, that neither of these agents is intended to be breathed, and that the safeguards surrounding the distribution of gases are so perfect that accidents from accidental leakage are of the rarest occurrence.

It is also easy to perfume the gas by slight additions of hydrocarbons, so that $\frac{1}{10,000}$ of one per cent. may be detected by the sense of smell.

While, therefore, it is undoubtedly true that the toxic effects of water-gas are more decided than those of common coal-gas, the judges, in view of the facts above named, do not believe that this

constitutes an objection of sufficient weight to warrant the condemnation which some alarmists have cast upon it.

The judges are unanimous in the opinion that the display of the capabilities of water-gas for fuel purposes, made by the Lowe Manufacturing Company, was a most instructive and creditable one.

CARBURETTED WATER–GAS.

The carburetted water-gas was made simply by allowing the gas from the gas holder to pass through the carburetter, and saturate itself mechanically with the gasolene vapor. In this condition it was used principally by the Siemens-Lungren Gas Light Company for lighting a portion of the main avenues. The judges submitted the gas to photometric examinations, with the following results:

PHOTOMETRIC RECORD.

(*Observers: Greene, Marks, Wahl and Ward.*)

Gas consumption per hour,	3·9 cubic feet.
Ignition pressure,	0·15 inches.
Burner U. S. Standard.	
Illuminating value,	18·33 candles.
Equivalent candle-power, at five feet consumption,	23·50 candles.
Candles per cubic foot,	4·7

THE LOWE INCANDESCENT GAS LIGHT.

This light is obtained by allowing the non-luminous water-gas to impinge upon a spiral wire of platinum or platin iridium. Several forms of this burner are used. Those shown at the exhibition and examined by the judges were formed of a stout wire of horse-shoe shape, the ends of which were attached to a brass collar and fitted snugly upon the ordinary lava tip slit burner. Upon this stout wire there was tied by means of a fine wire of the same material a close spiral of platinum, or platin-iridium, the stout supporting wire being placed on the upper or outer surface of the curve formed by the spiral. The size of the horse-shoe varies with the size of the burner on which it is intended to be used.

They were shown singly, or in groups, or clusters, upon chandeliers of the ordinary pattern, and upon specially designed fixtures, in several of the avenues and in the tastefully decorated rooms occupied by the Lowe Manufacturing Company.

The adjustment of the spiral is such that the flame of the gas shall surround it, so that every part thereof may be equally heated

by it. To do this properly requires that the alignment of the spiral with respect to the flame shall be perfect, and that the orifice from which the flame issues shall be kept free from dust or other obstruction, otherwise the unequal brightness of the spiral becomes at once apparent.

Observations of these lights at the exhibition and at the company's works, at Norristown, warrant the judges in the belief that these requirements present no serious difficulties in practice. When the gas is lighted, the spiral at once becomes brightly luminous, affording a steady uniform light, which at first suggests to the observer the well-known incandescent electric light.

The judges have no data upon which to estimate the average life-duration of these burners, the opportunity for such tests as would be required to determine this question, not having presented itself. It may be proper to state, however, that the Lowe Manufacturing Company claims to have had 2,000 hours of service from experimental burners of this type, without appreciable deterioration.

It is alleged, likewise, that the question of durability is of secondary importance, since when spirals cease to act satisfactorily from any cause, they will still be worth the weight of the metal they contain, and may be exchanged for new spirals at a fractional cost above that of the metal.

The results of photometric tests of a series of these spirals, using Lowe Fuel-Gas, manufactured on the exposition grounds are given herewith :

PHOTOMETRIC RESULTS.

(*1.—Observers: Marks, Wahl and Ward.*)

Gas consumption per hour, ...	9·69 cubic feet.
Ignition pressure, ...	2·25 inches.
Illuminating value, ...	12·85 candles.

Equivalent to 1·33 candles per cubic foot.

(*2.—Observers: Wahl and Ward.*)

Gas consumption per hour, ...	8·31 cubic feet.
Ignition pressure, ...	2·37 inches.
Illuminating value, ...	10·88 candles.

Equivalent to 1·31 candles per cubic foot.

(*3.—Observers: Wahl and Ward.*)

Gas consumption per hour, ...	7·9 cubic feet.
Ignition pressure, ...	2·5 inches.
Illuminating value, ...	12·24 candles.

Equivalent to 1·55 candles per cubic foot.

(*4.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 6·7 cubic feet.
Ignition pressure, ... 1·75 inches.
Illuminating value, ... 8·48 candles.
Equivalent to 1·26 candles per cubic foot.

(*5.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 6·7 cubic feet.
Ignition pressure, ... 1· inch.
Illuminating value, ... 8·41 candles.
Equivalent to 1·25 candles per cubic foot.

(*6.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 5·58 cubic feet.
Ignition pressure, ... 3·25 inches.
Illuminating value, ... 9·94 candles.
Equivalent to 1·78 candles per cubic foot.

(*7.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 5·1 cubic feet.
Ignition pressure, ... 1·5 inches.
Illuminating value, ... 6·85 candles.
Equivalent to 1·34 candles per cubic foot.

(*8.—Observers: Wahl and Ward.*)

Gas consumption per hour, ... 3·96 cubic feet.
Ignition pressure, ... 2· inches.
Illuminating value, ... 5·49 candles.
Equivalent to 1·38 candles per cubic foot.

Mean of eight (8) experiments, 1·40 candles per cubic foot.

TABLE SHOWING RECORD OF PHOTOMETRIC TESTS OF THE LOWE INCANDESCENT LIGHTS.—GAS USED, LOWE WATER-GAS.

No. of Experiments.	*Gas Consumed in Cubic Feet per Hour.*	*Pressure at Burner, Inches.*	*Candle-Power.*	*Candles per Cubic Foot.*
1	9·69	2·25	12·85	1·33
2	8·31	2·37	10·88	1·31
3	7·91	2·5	12·24	1·55
4	6·7	1·75	8·48	1·26
5	6·7	1·	8·41	1·25
6	5·58	3·25	9·94	1·78
7	5 1	1·5	6·85	1·34
8	3·96	2·	5·49	1·38
Mean of eight (8) experiments, ...				1 40

From the results of these tests an approximate estimate of the cost of this light, as compared with ordinary illuminating gas, *light for light*, may be made as follows:

If we assume the cost (to consumers) of coal-gas of seventeen candle-power (equal to 3·4 candles per cubic foot) to be $1.50 per 1,000, the cost of water-gas must not exceed sixty-one and three-fourths cents per 1,000. If we assume coal-gas of seventeen candle-power to cost the consumer $1 per 1,000, the cost of water-gas must not exceed forty one and one-sixth cents per 1,000; or, in round numbers, sixty and forty cents, respectively.

In other words, to compete on equal terms with ordinary illuminating gas, the Lowe incandescent light will have to be supplied at two-fifths the cost of the former.

Whether such economy can be obtained, depends to a large extent upon the cost of distributing the gas, which will depend largely, in turn, upon the amount of consumption for fuel and lighting purposes; so that any estimate based upon the cost of gas in the holder, will be very misleading. On the question of economy, therefore, the judges refrain from expressing an opinion.

The judges availed themselves of the opportunity afforded them after the close of the exhibition, to make a second series of photometric measurements of the Lowe incandescent burners, with the object of verifying and controlling the results of their first set of observations. The results are given below, and show a satisfactory uniformity between the two sets of observations.

PHOTOMETRIC RECORD.—(Second Series.)

(*1.—Observers: Greene, Marks and Wahl.*)

Gas consumption per hour, ...	7·8 cubic feet.
Ignition pressure, ...	2·3 inches.
Illuminating value, ...	10·6 candles.

Equivalent to 1·36 candles per cubic foot.

(*2.—Observers: Greene, Marks and Wahl.*)

Gas consumption per hour, ...	9·9 cubic feet.
Ignition pressure, ...	2·1 inches.
Illuminating value, ...	12·83 candles.

Equivalent to 1·29 candles per cubic foot.

(*3.—Observers: Greene, Marks and Wahl.*)

Gas consumption per hour, ...	4·74 cubic feet.
Ignition pressure, ...	2·75 inches.
Illuminating value, ...	6·85 candles.

Equivalent to 1·45 candles per cubic foot.

Mean of three experiments, 1·37 candles per cubic foot.

TABLE SHOWING RECORD OF PHOTOMETRIC TESTS OF LOWE INCANDESCENT BURNERS.—GAS USED, LOWE WATER-GAS.

No. of Experiments. (2d Series.)	*Gas Consumed in Cubic Feet, per Hour.*	*Pressure at Burners, Inches.*	*Candle-Power.*	*Candles per Cubic Foot.*
1	7·8	2·3	10·6	1·36
2	9·9	2·1	12·83	1·29
3	4·74	2·75	6·85	1·45
Mean of three experiments, ...				1 37

The judges make the following recommendation: To the Lowe Manufacturing Company, Norristown, Pa., for substantial improvements in the manufacture of water-gas, and in appliances for using water-gas for fuel; for ingenuity displayed in methods for using water-gas for illuminating purposes, and for general excellence of collective exhibit of the capabilities of water-gas—

A SILVER MEDAL with a reference to the Committee on Science and the Arts, for such higher award as it may deem proper to make.

(SIGNED) WM. H. WAHL, *Chairman*,
WM. H. GREENE,
WM. D. MARKS,
L. B. HALL,
GEO. M. WARD, M. D.,
GRIFFITH M. ELDRIDGE.

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REPORT ON WATER-GAS.

By a Special Committee Appointed by the Judges of the "Novelties" Exhibition, Franklin Institute.

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